JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOLUME 41 May 1951 No. 5

PHYSICS.—*The limitations of the principle of superposition: II.*

PAUL R. HEYL, Washington, D. C.

The first paper on this subject was published in this JOURNAL **40**: 345, 1950, wherein the discussion was confined to the case of the resultant of components with equal frequencies. The present paper discusses the case where the frequencies are different. Here we find some rather unexpected results, all of which originate in one fundamental proposition—that with components of different frequencies the resultant does not obey Hooke's law.

Consider first the case of equal frequencies:

$$y = A \sin nt + B \sin n(t - \theta)$$
$$d^2y/dt^2 = -n^2 [A \sin nt + B \sin n(t - \theta)]$$

Assuming a vibrating element of unit mass, we see that the force acting on the element is proportional to the displacement, obeying Hooke's law.

With components of different frequencies,

$$y = A \sin nt + B \sin m(t - \theta)$$
$$d^2y/dt^2 = -An^2 \sin nt - Bm^2 \sin m(t - \theta),$$

where the force acting is not proportional to the displacement but is a variable function of the displacement. To see what results this brings we shall consider a very simple case:

$$y_1 = \sin t \qquad y_2 = \sin 2t$$
$$\text{Resultant} \quad y = \sin t + \sin 2t \qquad (1)$$

Table 1 gives numerical values of displacement, force acting and ratio of force to displacement for a number of points in the first half cycle.

The ratios at $t = 0°$ and $t = 180°$ are of an indeterminate form which, when evaluated, give the limits to which the ratios approach at the neighboring points.

It will be seen that the curve has a point of inflexion when $t = 97° 10' 50''$. Here the force acting is zero, while the displacement is not zero. A case of opposite kind is found when $t = 120°$. Here the curve crosses the axis and the displacement is zero, but the force is not zero.

A more readily understandable case of this latter kind is found if we consider a flexible string of length π, fixed at both ends and vibrating in its first and third harmonics (see Fig. 1). Here we have, at maximum displacement, $y = \sin x + \sin 3x$, with the middle point of the string on the axis of x. At this moment let the points B and C be held stationary. The middle point A will then snap upward and finally come to rest on the straight line between B and C, showing that it had a force acting on it when its displacement was zero.

FIG. 1

Another unexpected result appears also in this table. The displacement has a maximum when $t = 53° 37' 29''$, but the greatest force occurs at $t = 47° 25' 33''$. A similar result is found for the minimum value of y at $t = 147° 27' 37''$, with the maximum force at $t = 137° 39' 1''$.

Let us now consider the question of energy. The components $y_1 = \sin t$ and $y_2 = \sin 2t$ have respectively total energies of $\frac{1}{2}$ and 2, whose sum is 2.5. What will be the energy of their resultant?

$$\text{Kinetic energy} = \tfrac{1}{2}(dy/dt)^2$$
$$= \tfrac{1}{2}(\cos t + 2 \cos 2t)^2$$
$$= \tfrac{1}{2} \cos^2 t + 2 \cos^2 2t + 2 \cos t \cos 2t \ldots (2)$$

The first two terms of (2) represent the kinetic energies of the original components y_1 and y_2. The third term is an excess (or deficiency) of kinetic energy which is introduced by adding amplitudes, since the square of a binomial may be greater or less than the sum of the squares of its two terms. If $t = \pi/4$ or $\pi/2$ there will be no excess or deficiency, and only in such cases will superposition be valid.

To determine potential energy we must know the force necessary to balance the force of restitution. $d^2y/dt^2 = -\sin t - 4 \sin 2t = -F$, the force of restitution, negative when displacement is positive. Therefore F will be the force we need to determine potential energy. Both F and y are functions of t.

$$\text{Potential energy} = \int_0^y F\,dy = \int_0^t F\,dy/dt\,dt$$

$$= \int_0^t (\sin t + 4 \sin 2t)(\cos t + 2 \cos 2t)\,dt$$

This splits up into four integrals.

$$\int_0^t \sin t \cos t\,dt = \tfrac{1}{2} \sin^2 t \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$2\int_0^t \sin t \cos 2t\,dt = \cos t - \tfrac{1}{3} \cos 3t - \tfrac{2}{3} \quad \ldots (4)$$

$$4\int_0^t \sin 2t \cos t\,dt = -\tfrac{2}{3} \cos 3t - 2 \cos t + \tfrac{8}{3} \quad \ldots (5)$$

$$8\int_0^t \sin 2t \cos 2t\,dt = 2 \sin^2 2t \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Here we see that with more than two components the mathematical labor rapidly mounts up. With two components we have four integrals to handle; and with ten components we would have a hundred integrals. But, as was mentioned in the first paper on this subject, there are a number of cases of practical importance where the traditional addition of amplitudes gives correct results.

The sum of these four integrals will be the potential energy of the vibrating element at displacement y. Of these four, (3) and (6) will be the potential energies of the components y_1 and y_2. The sum of (4) and (5) will be the excess (or deficiency) of potential energy in the resultant. Adding the kinetic energy (2) to the sum of these four integrals we have

$$\text{Total energy} = \tfrac{1}{2} + 2 + 2 \cos t \cos 2t - \cos t - \cos 3t + 2,$$

in which the trigonometric terms cancel out after a little reduction,[1] and we have

$$\text{Total energy} = \tfrac{1}{2} + 2 + 2 = \text{component energies} + 2 \text{ units excess} \quad (7)$$

which is constant for all values of t.

This violation of the conservation of energy can be avoided by applying modifying factors to the original components y_1 and y_2 before adding their amplitudes. Let these factors be M_1 and M_2. The modified components will be

$$y_1' = M_1 \sin t \text{ and } y_2' = M_2 \sin 2t, \text{ and their resultant } y = M_1 \sin t + M_2 \sin 2t \quad (8)$$

Working with (8) as we did with the resultant of the original, unmodified components, we obtain

$$\text{Total energy of (8)} = \tfrac{1}{2}M^2_1 + 2M^2_2 + 2M_1 M_2 \quad (9)$$

TABLE 1

t	y	d^2y/dt^2	Ratio
0°	0	0	0/0 = −3.00
20°	0.98481	−2.91318	−2.95
40°	1.62670	−4.58203	−2.81
47° 25′ 33″	1.73280	−4.72200	−2.73
50°	1.75085	−4.70528	−2.69
53° 37′ 29″	1.76014	−4.62520	−2.53
60°	1.73206	−4.33315	−2.48
90°	1	−1	−1.00
97° 10′ 50″	0.74412	0	0
100°	0.64279	0.38327	0.60
110°	0.29690	1.63147	5.49
115°	0.14027	2.15785	15.39
120°	0	2.59809	∞
125°	−0.07946	2.93961	−37.00
130°	−0.21877	3.21732	−14.69
137° 39′ 1″	−0.32206	3.30922	−10.28
140°	−0.34202	3.29645	−9.64
147° 27′ 37″	−0.36901	3.08944	−8.37
150°	−0.36603	2.96412	−8.10
170°	−0.16837	1.19443	−7.11
180°	0	0	0/0 = −7.00

[1] The terms in question are:

$$2 \cos t \cos 2t - \cos t - \cos 3t \quad (1')$$

$\cos 3t = \cos(t + 2t) = \cos t \cos 2t - \sin t \sin 2t$

Substituting this, the terms in question become

$$\cos t \cos 2t - \cos t + \sin t \sin 2t \quad (2')$$

Now $\cos t \cos 2t + \sin t \sin 2t = \cos(t - 2t) = \cos(-t) = \cos t$

Substituting in (2′), the terms all cancel out.

Equating this to the sum of the energies of the original components we have one equation for M_1 and M_2.

$$\tfrac{1}{2}M^2_1 + 2M^2_2 + 2M_1 M_2 = \tfrac{1}{2} + 2 \qquad (10)$$

A second equation for M_1 and M_2 is needed.

It is physically reasonable to suppose that the original components y_1 and y_2 should contribute to their resultant in proportion to their respective energies. Therefore the coefficients of y'_1 and y'_2 should be proportional to the square roots of the energies of the original components.

$$\frac{M_1}{M_2} = \left(\frac{\frac{1}{2}}{2}\right)^{\frac{1}{2}} = \tfrac{1}{2}$$

which gives $M_2 = 2M_1$. Eliminating M_2 between this and equation (10) we get

$$M_1 = 5^{-\frac{1}{2}} \qquad M_2 = 2(5)^{-\frac{1}{2}}$$

and the resultant becomes

$$y = 5^{-\frac{1}{2}} \sin t + 2(5)^{-\frac{1}{2}} \sin 2t \qquad (11)$$

whose total energy for all values of t is equal to 2.5, the sum of the energies of the original components.

For more than two components the foregoing is easy to generalize. For n components there will be n modifying factors. In addition to the generalized form of (10) there will be $(n - 1)$ ratios between the n modifying factors, giving n equations for their determination.

Table 2 gives for the resultant (11) values of displacement, force acting and ratio of force to displacement for points in the first half cycle, as in Table 1. In addition this table gives energy values.

It will be seen in this table that while the total energy remains constant the kinetic and potential energies fluctuate, the potential energy having maxima corresponding to the maximum and minimum values of y; and at these points the kinetic energy is zero. The same peculiarities found in Table 1 occur here; potential energy and d^2y/dt^2 do not have the same maxima, and the values of the ratios at 0° and 180° are indeterminate and the evaluated values are given.

TABLE 2

t	y	d^2y/dt^2	Ratio	Potential energy	Kinetic energy	Total energy
0°	0	0	−3.40	0	2.5	2.5
20°	0.727883	−2.45319	−3.37	0.896899	1.60309	2.49999
40°	1.168301	−3.81081	−3.26	2.28665	0.21335	2.50000
46° 14′ 20″	1.216580	−3.89735	−3.20	2.47308	0.026908	2.49999
49° 39′ 25″	1.223492	−3.87154	−3.17	2.50000	0	2.50000
50°	1.223424	−3.86594	−3.16	2.49973	0.00027	2.50000
70°	0.995171	−2.73027	−2.74	1.75899	0.74101	2.50000
90°	0.447214	−0.447214	−1.00	0.9	1.6	2.5
93° 35′	0.334754	0	0	0.87490	1.62510	2.50000
100°	0.134506	0.78323	5.82	0.95361	1.54639	2.50000
104° 28′ 39″	0.000001	1.29904	∞	1.09375	1.40625	2.50000
110°	−0.154683	1.88978	−12.22	1.33978	1.16023	2.50001
130°	−0.538252	3.18076	−5.91	2.32114	0.17886	2.50000
136° 17′ 42″	−0.584481	3.26856	−5.60	2.47062	0.02939	2.50001
140°	−0.593375	3.23589	−5.45	2.49948	0.00051	2.49999
140° 34′	−0.593533	3.22632	−5.42	2.5	0	2.5
150°	−0.550992	2.87464	−5.22	2.37141	0.12859	2.50000
170°	−0.228255	1.14599	−5.02	1.73051	0.76948	2.49999
180°	0	0	−5.00	1.6	0.9	2.5

ETHNOLOGY.—*Some medical beliefs and practices of the contemporary Iroquois Longhouses of the Six Nations Reserve.*[1] MARCEL RIOUX, National Museum of Canada, Ottawa, Canada. (Communicated by William N. Fenton.)

A member of an Iroquois Longhouse is considered to be an individual who does not belong to any of the Christian sects and is regarded by his fellow members as a believer in the doctrine of Handsome Lake, a native prophet who, at the beginning of the nineteenth century, established a new religion among his people. Although this doctrine is strongly influenced by Christian beliefs and practices, it has served to preserve and consolidate many traditional Iroquois ideas and customs. The name "Longhouse" also designates the building where the adherents of the Handsome Lake cult hold most of their religious rituals and ceremonies. The percentage of the Longhouse worshipers is about one-fifth of the Iroquois population—approximately 5,500—of the whole Six Nations Reserve. The majority are located on the "lower"[2] end of the reserve and form a homogeneous group; the Christians in this area are very few. Three of the four Longhouses on the reserve are located there, and the fourth, the Upper Cayuga Longhouse, stands just beyond the boundary of what could be considered the Longhouse district. The affairs of both the Pagans and the Christians are taken care of without discrimination by the Indian Affairs Branch of the Canadian Government. Between the two groups no other frontier exists but the cultural, and both have practically the same historical background.

Every Iroquois tribe is represented on the reserve, but unevenly. Almost all the Mohawks, Oneidas, and Tuscaroras, who represent more than three-fifths of the entire population, are Christians; the next fifth of Christians consists of Senecas Kanedagas, Onondagas Bearfoot along with some Upper Cayugas, and a few Lower Cayugas. The Cayugas form the bulk of the Longhouse believers; among them, the Lower Cayugas, who are more numerous than the Upper, are the most coherent Longhouse group. The Upper Cayugas alone are located outside of the Longhouse area. This group has shown signs of disintegration in recent years, and members are not so staunch in their outlook and practices as they used to be. Whereas the Mohawks, Cayugas, Oneidas, and Tuscaroras constitute homogeneous religious groups, the Senecas and Onondagas are divided among themselves. Should we follow in our analysis the paternal line of descent, as is done officially by the Indian Affairs office, and increasingly by the Longhouse themselves who abandon the traditional maternal line, we will find that no Longhouse worshiper is found among the Bearfoot Onondagas, while there are not more than two or three among the Senecas Kanedagas. On the other hand, most of the Onondagas Clearsky and the Senecas Wharondas or Aughanagas are Longhouse supporters. Are the roots of this divergent religious evolution historical or could this split be explained in terms of the present location of the various tribes and subtribes of the Reserve? We note that most of the Senecas and Onondagas who live among the Cayugas belong to the Handsome Lake religion, and those living with the Mohawks are Christian.

Although a full explanation of the actual state of the beliefs and practices of the Longhouse people concerning medicine could not be reached before other aspects of their culture are taken into account and discussed in relation to one another, a brief outline of some of the points under study is given here.

A cultural trait, it seems, may be replaced only when the borrower finds in a new trait an advantage over the one being discarded, and when the new trait can be readily assimilated by the old culture. To explain the diffusion of technical traits from one society to another, one has to find out whether the dominated society is at a favourable enough technical level to make use of the traits which are offered to it. Leroi

[1] I spent part of the summers of 1949 and 1950 among the Long-house Iroquois of the Six Nations Reserve near Brantford, Ontario, with the view of determining the degree and rhythm of acculturation of this social group. The survey was sponsored by the National Museum of Canada, Ottawa.

[2] This designation appears to be not merely geographical; it connotes a value-judgment when uttered by Christian Iroquois of the "upper" end.

Gourhan[3] states that diffusion does not take place when (1) the ethnical group, being in a state of technical inferiority cannot understand the principles of the new technical traits, (2) when an ethnical group, being in a state of technical inertia, does not see the need of making any effort to assimilate the new traits, and (3) when the ethnical group, being in a state of intensive technical development, neglects what other groups have to offer. Could we not add that there are cases of partial diffusion when a group, for pragmatic reasons, accepts certain new traits and still keeps the older complex because its ideological culture, which does not follow the same rhythm of acculturation as the technical and social cultures, is still linked with the older technical traits?

These principles could explain the adoption by the Iroquois of a vast amount of European technical traits and the abandonment of practically all their technical culture. The few native traits still retained mostly appertain to medicine. In the old Iroquois culture, medicine formed a focus of importance, secondary only to political organization and to the agricultural complex, and for this reason, it should subsist longer than other complexes of lesser importance. Medicinal beliefs and practices, intimately linked with their traditional rituals and mythology, remain in accord with the structure of their personality, which has not changed as fast as the external aspects of their culture. Their great mechanical ability has enabled them to grasp the intricacies of much of the European technology and to assimilate it; yet, on the whole, some of their cultural postulates or themes have prevented them from discarding magical beliefs and practices. As we shall see later, native medicine and European medicine can coexist, while some practices cannot continue to exist in the presence of others and have, as a matter of fact, disappeared or are regressing constantly. For instance, the folk are still very fond of corn bread, yet they do not as a rule take the trouble to use it because their modern habits do not leave them enough time to prepare it.

[3] LEROI-GOURHAN, ANDRÉ, *Milieux et techniques:* 398–399. 1945.

Their medicine may be divided into two parts: the first rests on their traditional knowledge of the curative properties of herbs and other plants; it is empirical. The other may be called magical; it consists of beliefs and practices in which, from the point of view of the observer, no logical link is apparent between the means taken for a cure and the results expected. As Murdock[4] points out, magical beliefs and practices are characterized, among other things, by effort to produce effects "in following out some mystical principle or association of ideas." For instance, a fortune-teller says to a dyspeptic person: "You must hold an Eagle dance because your mother when alive, used to put on an Eagle dance from time to time. But since she died nobody has ever given one." We may now ask whether the Iroquois make a distinction between these two types of medicine, empirical and magical. Observations to be given here presently, tend to show that they make a distinction between the two kinds of medicine but that it is not made at the intellectual but at the affective level; they seem to yield to different kinds of sentiments when, on the one hand, they go to the hospital and when, on the other hand, they resort to the fortune-teller or to the witch. On the whole, they are inclined to resort to the white doctor or to their medicinal plants whenever their ailment appears to them as being well localized and easy to diagnose; but they turn to a fortune-teller and sometimes to a witch when their trouble seems mysterious. As an informant stated, some diseases are for the white doctor to cure and others for the fortune-teller. Their basic criterion for establishing a distinction between the various ailments they suffer appears to be the element of mystery lacking in the first and present in the others; their emotions rise in intensity in proportion with the mystery involved; they soon pass from fear to anguish.

If we call empirical that part of Iroquois medicine which is based on the knowledge of the curative properties of plants and herbs, we can state that this practice does

[4] MURDOCK, G. P., in *Dictionary of sociology*, Fairchild, H. P. (ed.): 180.

not belong exclusively to the Longhouse worshipers; for some of the Christians still use Iroquois medicine. But, as everything traditionally Iroquois, it has a tendency to be identified with Longhouse people and culture. In a few cases of passage from Christianity to the Handsome Lake religion, the reason given to me for the conversion was the good effect Iroquois medicine had on some people who were very ill. Because the whites often express their confidence in and admiration for Iroquois medicine, the Christian Iroquois still keep a verbal, if not a practical, attachment to their own tradition. As this does not conflict with their Christian faith, it has been kept as a compensatory element; there is a strong inclination to retain it in both Christian and Longhouse groups, because it belongs to them and for that reason, has become a source of pride. To overcome the complex of inferiority they have towards the white, they are apt to boast that they had and still have a powerful medicine.

If empirical Iroquois medicine is idealized more than practiced among the Christians it is still in use among the Longhouse people who link it with the Handsome Lake religion and native beliefs and customs. Today medicine has gathered around itself other traits which formerly were not so intimately linked with it. If the Iroquois institution of giving personal names is still maintained by a good many Longhouse adherents, it is done, so some chiefs say, to keep the medicine practices functioning. In some rituals, especially where a tobacco offering is made, the name of the person for whom the ritual is performed must be mentioned; as the rituals are conducted in the Indian dialect, the name itself should also be mentioned in that tongue because if the name were uttered in English (Christian name) the Great Spirit would not know the person concerned. Medicine appears to be one of the last Indian complexes the Longhouse will abandon; it is of great importance in keeping their culture functioning as distinct from that of the whites. As early as in 1912, Goldenweiser wrote: "The Societies of the Iroquois, whatever their history may have been, are at the present time medicinal in their functions."[5] Most of the societies he mentions have kept functioning today despite the increasing pressure of the white culture; it is mostly around this medical complex that the cultural resistance to assimilation has centered and crystallized. At the Green Bean Festival of last summer, I met a young man who had moved out of the Longhouse district some years ago and is now working among the Christian Mohawks. As he belongs to a family of Longhouse believers, he comes back to the Longhouse for seasonal festivals, and came this year as usual. But he stayed in his car instead of joining the dance inside. He was on the verge, so he confessed to me, of abandoning that religion and of becoming a Christian; the only reason which kept him from making this move, said he, was the Iroquois medicine. "If I quit, I will lose all the benefits of our good medicines, and these I don't want to give up."

The economic aspect of medicine, which in peasant societies plays an important role in the retention of folk practices, works here in the opposite way. In French Canada, for example, the physician lives ordinarily far from the farms and charges his customers for his services; these factors influence the peasant to cling to his old ways. At the Six Nations Reserve the doctors and hospital are located near Indian homes and their medical services to the natives are given free. On this same question of empirical medicine, there exists another difference between the practices of the peasant and the Iroquois. As the plants and herbs of the Iroquois belong to the past when the tribes lived in the woods in the midst of an undisturbed native flora they are now scarce and difficult to find. The peasants, on the contrary, use plants and herbs usually domesticated and close at hand.

When it comes to magical medicine, the split between Christians and Longhouse people becomes more accentuated. Although there are instances in which Christians have, in desperate cases, resorted to the fortune-teller, they are becoming rarer every year.

[5] GOLDENWEISER, A. A. "On Iroquois Work," in *Summary Report of the Geological Survey:* 464–475. Department of Mines, Ottawa, 1912.

The Christians, as a whole, have forsaken the rituals and observances connected with medicine and even if a fortune-teller told one of them to put on a Buffalo dance, he would not be able to perform it or to have it performed by his neighbour. The Christians have been under the influence of the church for so many years—about 300—that they have lost even the idea of the fortune-teller or the witch.

The beliefs and practices of the Longhouse are not altogether uniform. Various degrees of acculturation prevail here. Some people are more conservative than others; some are becoming open to outside influences. But, on the whole, they have a corpus of beliefs and of conscious and unconscious attitudes which link them together very strongly. Among them, we find three categories of medical practioners. The Indian doctor proper is the best known among the whites, as he often dresses in ceremonial garments, takes part in exhibitions, county fairs, and sells medicine outside the Reserve; he acts like an emissary of Iroquois culture. There are now two or three Indian doctors of this type on the Six Nations reserve Though their journeys and association with the whites have won them some prestige among their Longhouse compatriots, they do not enjoy the same esteem among their people as does the fortune-teller or even the witch. The folk are inclined to talk about them with a little disdain and to remark that this kind of a doctor is primarily a moneymaker; they do not consult him as often as the others; they may be proud of his successes at large but as he does not often associate with them, their preference goes to the fortune-tellers and the witches who join them in all ceremonies and rituals.

The fortune-teller, a man or woman, is not outwardly different from the other Longhouse people. But he or she is a person "who knows a lot of things" and this knowledge carries great prestige among the conservative elements of the population. He does not usually ask for money in payment for his services, but tells his patients to give him what they consider fair compensation. His ways of finding out what is good for a patient are many: dreams, leaves of tea, cards, the absorption by himself of certain medicines, simple questioning, and the summary examination of the patient. His prescriptions are varied: herb and bark medicines, mixed plant and magical recipes, or just magical devices. He stands midway between the European doctor who resorts only to empirical medicine and the witch who resorts to magic. At times, the fortune-teller introduces preventive medicine by ordering, at the beginning of summer or winter, a remedy which keeps away the diseases common in that season of the year; this practice is dying out. Most of his efforts, however, are directed to mysterious and difficult cases, where he will ordinarily prescribe a ritual dance, a feast or a game with or without the use of herbs and plants.

The third group of practitioners concerned with health is more exclusive and very secretive. It takes a long time for an outsider to learn their names and to get any information about their black art. People ordinarily resort to the witches[6] when all other means have been exhausted. As it is admitted, witches are becoming rare and their activities are hidden even to the Longhouse believers themselves. According to some informants, those who aspire to become witches must try their power on a member of their own family by bewitching this person to death. For this very reason even their names remain secret. No witch can denounce another witch without denouncing himself. The feelings of the people in regard to witches and to witchcraft are ambivalent. On the one hand, the witch is feared and reprobated for his malefic power; and the code of Handsome Lake is very severe for witches. But, on the other hand, the people cannot help being fascinated by his great powers and they try to know their names and to get in touch with them. The best and the worst are often intimately linked, and excessive admiration and reprobation are sometimes merged in the minds and reactions of the people. Maleficious witchcraft and benevolent medicine are closely connected and the same plant may at times be used for both medicine and witchcraft, depending on the intentions of the person who collects the roots from which the powerful medicine or magic is

[6] "Witch" is used on the reserve for both male and female practitioners of witchcraft.

extracted. The more beneficial a medicine is, the worse it can be if used to bewitch. Their most powerful medicine today, according to my informants, is Nīganĕga'a', a powder extracted from a plant which is said to grow only at Salamanca, in New York State. Those who go there to collect the plant from which the "good medicine" is extracted observe strict rules; they must follow the plant with their hands from the top to the tips of the roots, deep in the soil. If the plant breaks during the operation, the search for another must start all over again as only plants pulled up in their entirety without being broken in any of their parts are suitable. Even when the ends of the roots have been reached without accident the only roots that are brought are those which grow from the east to the west—in the direction that the sun follows. Those growing from the North to the South must be avoided. However, somebody whose ambition it is to become a witch can pick these roots; they are used for the most powerful witchcraft. It is admitted, however, that the younger generation knows very little now about witchcraft; beliefs and practices are being lost; the idea of witchcraft is still entertained by a good many people but the witches themselves seem to be less active and less numerous.

Of the medicine men enumerated above, the fortune-teller is today the most active among the Longhouse people of the Six Nations Reserve. Of them Parker says: "Diviners of mysteries have always been prominent among the Indians. Their office was to tell their clients the proper medicine society that would be more efficacious in curing the sick, to discover the whereabouts of lost children and articles, to discover what witch was working her spells, and to tell fortunes, as well as to interpret dreams."[7] The function of the fortune-teller is similar nowadays, except that the first function described by Parker is much more to the fore than the others. The only other comment to be made on Parker's quotation is that witches may be male or female, not only female as he seems to imply. Indeed, the best-known witches now are mostly men.

[7] PARKER, ARTHUR. *The code of Handsome Lake:* 49–50. 1012.

A question comes up as to a possible parallel between the switching of this function from women to men and the constant regression of what was known as the Iroquois matriarchate. The people usually resort to the fortune-teller for illnesses which appear mysterious to them, mostly internal diseases with many symptoms. Although I know of a man having gone to a fortune-teller for appendicitis, diagnosed as such by a white doctor, and another one for an abscess in the leg, it seems that in such cases most Longhouses would have gone to the hospital. Acculturation processes[8] have been in operation for so long that it is safe to state that in most instances where the diseases are external and well diagnosed, the patients consult the doctor first before going to the fortune-teller or to the witch.

The wife of one of my informants came back from the fruit country where she had been "picking" for about two months and complained about her health. She had a poisoned tooth and felt other symptoms that made her "very sick." She had lost her appetite, was dizzy at times, and in the morning had a funny taste in her mouth; she also had pains in the abdomen. As she was going to the hospital to have her tooth extracted, I advised her to consult the doctor about her other troubles. She answered that it was not a case for the doctor but for the fortune-teller. She went to the hospital, came back three or four days later, and called the fortune-teller who told her that her dead husband was hungry and she must "put up" a feast for him. Obviously, there was in her mind a clear distinction between various illnesses: the ones which can be cured by the doctor, the others by the fortune-teller.

In another family I often visited, the mother told me she was not feeling well; she had about the same symptoms as the other woman just mentioned: loss of appetite, dizziness, pains in the head. She went to the fortune-teller who recommended a Bear dance; she was very grateful to him because she got better a few days after. Some time later, her oldest son was hit when stepping off a truck, and was bleeding

[8] FENTON, W. N. *Contacts between Iroquois herbalism and colonial medicine.* Ann. Rep. Smithsonian Institution, 1941: 501–526.

heavily; her first thought was to call for a doctor and to take her son to the hospital. As in the previous instance, the woman believed that one disease was to be cured by the fortune-teller, another by the white doctor.

Many people, however, do not take chances and go to both the doctor and the fortune-teller for the same illness. It sometimes happens that having gone first to the physician they stop seeing him and consult a fortune-teller, particularly when a long treatment is required; very soon they get discouraged and revert for help to their magical practices and medical societies. In many cases when they call the doctor, it is really too late. Seeing that their medicine has failed, they call for the doctor and sometimes go the the hospital just to die. This practice does not improve people's confidence in the hospital.

I have studied the life of a Lower Cayuga of the Handsome Lake faith who, in many respects, is typical of his culture; he has spent all his life on the reserve, in the Longhouse area, and has undergone the same influences as the majority of his fellow-believers. But even among the Longhouse believers, the effects of acculturation, as I have been able to observe them, are not uniform. Some people are very conservative on certain points while partial to new beliefs and practices. It seems that idiosyncrasies have much to do with the picking up of traits within a certain range. The informant just referred to, in matters of rituals and religious beliefs, is very strict while he could not help laughing at some of the Iroquois folk tales and myths; his wife, on the contrary believed in all myths and tales while she did not care very much for the rituals. In all matters of health and medicine, he was a very good informant because, being sick himself, he was personally interested. At various periods of his life, he had consulted the doctor for himself and for his family. As the doctor usually was successful, he had developed a high opinion of him and of his medicine. But I found that on serious matters, he had not taken chances, and he has used both the doctor and the fortune-teller. He is a member of the Bear, Otter, Eagle, and False Faces societies, all of them concerned with health. From time to time he "puts up" a dance to prevent any illness caused by negligence in not keeping the rules of the societies. In going over the various illnesses he and his family suffered, I am unable to detect the reasons he had gone to the doctor in certain cases and to the fortune-teller in others; except for face distortion and nose bleeding which are ailments for the False Faces to cure, I could not ascertain on what grounds the distinction between illnesses was made. Some of the illnesses began while the family was out in the fruit country where a fortune-teller was not available; had they happened on the reserve it might have been different; in other cases, the doctor or the fortune-teller was called, when one or the other failed to give satisfaction.

About five years ago, Pat fell from a barn, and although no bone apparently was broken he called for the fortune-teller to administer him some "Nīganĕga 'a'", the good medicine." As it did not work—nothing was broken—he called a doctor, because he still felt very sick. After a thorough examination the doctor said that nothing was wrong with him and gave him some pills. Since that day, however, he has not been able to work; he always complained about headaches and stomach and intestinal troubles. Once in a while he calls on a doctor—every time a new one comes on the reserve—and now and then he sees a fortune-teller. When he finds that the prescription of the fortune-teller does not cure him, he is apt to think that he has not enough confidence in the traditional dances and feasts and blames it on himself for not being cured.

One day, after discussing his problems, he told me that the only answer was that he had been bewitched; the more he thought of it, the more he believed that he had all the symptoms of a bewitched person. "When nobody knows the cause of headaches, pains, loss of appetite, it is sure that the one who suffers these ailments has been bewitched." It was the first time he mentioned this suspicion to me, yet it had occurred to him long ago, as soon as the doctor he had consulted first had told him he did not know what was wrong with him. For a year now his conviction had grown firmer; his wife had

then consulted a fortune-teller who was picking berries with her and told her that she knew that Pat, my informant, had been bewitched by a relative of his who had reasons to compalin about his behaviour. From that time on he was busy with his wife trying to find out the person who had caused harm to him. Every possibility was examined patiently and finally the conclusion was reached that it was a woman with whom he had had some trouble about a horse and a succession. This particular woman seemed to fit the words of the fortune-teller: she was a relative, she might have had some reasons to be angry at him and she was thought by many to have practiced magic in the past and still to practice it. But his trouble did not end there. Pat had then to find another witch who could counterbalance the influence of the first. As the activities of the witches are secret and are known only by hearsay, finding a stronger one was by no means easy. The only one in sight, powerful enough, was not on good terms with him. At the time he took sick, five years ago, this witch, who is also a fortune-teller refused to give him "good medicine," under the pretext that he did not have enough of it; my informant had to beg the Onondaga keeper of the medicine for it, which he did not like to do. This medicine is all the same whether it comes from an Onondaga or from a Cayuga, but the portion that the Cayuga keeper has should be used for Cayugas. Since that time, he has hardly talked to him, and now feels hesitant to ask any other favours. As a result of this, my informant was getting more and more perplexed, and the idea that he was bewitched never ceased to grow with him.

An example of the use of both empirical and magical medicine is that of a young man lying in bed with fever. One morning he told his parents that he had seen many little men going up and down on his bed. The parents decided that, on account of this vision, he should be made a member of the Pigmy Society; the same day, the doctor, who had been called previously, decided to bring the lad to the hospital; and the parents, who had decided to put up a "Dark dance," had to have this done the night after his departure. As he was away, his shirt was placed on a chair to signify that the ceremony was conducted for him, in his absence.

The activities of Iroquois practitioners do not keep their people from going more and more to their own hospital on the reserve. As they are generally less aggressive than the Christians, they are prone to take advantage of the facilities which the whites have placed at their disposal. Yet, in many cases, their stubborn conservatism prevents the Longhouse people, and for that matter the Christian Iroquois as well, from going away from their relatives and friends; they fear any new contacts they may have to make at the hospital. As in peasant societies the in-group-belonging remains strong, despite the constant pressure urban culture exercises on both societies.

Their use of both empirical and magical medicine appears to be a double-security system for the individual. Just because the white medicine succeeds in many cases they do not lose confidence in their own medicine. The differences between these two systems do not bother them very much. They see the white medicine with their own eyes. Not knowing the principles of this medicine, they are apt to think of the white doctor as another kind of fortune-teller. The latter at times mixes empirical and magical medicine and they are not astonished at the practices of the white doctor. It is probably because they make no clear distinction between the two that they also expect from the white doctor a quick cure. Examples of rapid cures are quoted with great admiration and a long cure is no cure. "Next day he was better and went to work" is the happiest solution and the only one worth mentioning.

In further studies on this subject, I will try to show that if some of the old beliefs and practices concerning medicine are still entertained among the Iroquois Longhouse it is because their personality has not been acculturated at the same rhythm as the rest of their culture and that there is still room for faith in magic.

GEOLOGY.—*Present Cretaceous stratigraphic nomenclature of northern Alaska.*[1] GEORGE GRYC, W. W. PATTON, JR., and T. G. PAYNE,[2] U. S. Geological Survey. (Communicated by W. F. Foshag.)

Until 1944, geologic investigations in northern Alaska were of a reconnaissance nature and few stratigraphic units were recognized and named. Since 1944 the U. S. Geological Survey in cooperation with the U. S. Navy has been investigating the petroleum possibilities of Naval Petroleum Reserve No. 4. These investigations have covered nearly all northern Alaska from the Jago River west to the Kukpowruk River and from the Arctic Ocean south to and in several places into the Brooks Range (Fig. 1). This work has resulted in much more detailed information on the geology of the region. Rocks ranging in age from questionable pre-Cambrian to Pleistocene have been mapped and drilled. Cambrian, Ordovician, and Silurian rocks are not known to crop out north of the crest of the Brooks Range, but all other systems are represented (Fig. 2). To date the Cretaceous rocks have been studied more intensively than the rocks of any other age, and as a result a more detailed classification has been achieved (Fig. 3).

The Cretaceous rocks in the Anaktuvuk (Anaktoovuk) River area of northern Alaska were first described by Schrader.[3] Smith and Mertie[4] redefined the age of some of these rocks and added descriptions of their distribution and lithology. The present study has resulted in many changes in the stratigraphic classification. It is not always possible to tell from the literature what rocks have been included in previously described stratigraphic units and therefore these units may not be strictly comparable to the stratigraphic units introduced here. The apparent relationship of past and present stratigraphic nomenclature is shown in Table 1.

[1] Published by permission of the Director, U. S. Geological Survey.

[2] Authors listed in alphabetical order.

[3] SCHRADER, F. C., *Geological section of the Rocky Mountains in northern Alaska.* Bull. Geol. Soc. Amer. **13**: 247. 1902.

[4] SMITH, P. S., and MERTIE, J. B., JR., *Geology and mineral resources of northern Alaska.* Bull. U. S. Geol. Surv. **815**: 196–232. 1930.

The new classification is here presented and discussed. This classification is based on geologic field studies of the outcrop areas and on laboratory studies by the U. S. Geological Survey during the period 1944 to 1951.

CRETACEOUS ROCKS

Lower Cretaceous

OKPIKRUAK FORMATION (NEW)

The Okpikruak formation (new) is typically exposed along the Okpikruak River, from which it is named. The type section lies in the middle of a major syncline and is exposed on a small tributary of the Okpikruak River at about lat. 68°34′30″N. and long. 153°38′W. The formation crops out in the southern part of the Arctic Foothills province from the Itkillik River west to the Kukpowruk River. In the Arctic Foothills province, as far as known, it rests on Jurassic or Triassic rocks with little or no angular discordance. At its type locality it is about 2,400 feet thick. To date this is the greatest thickness measured, but an erosion surface between it and the overlying Torok formation indicates that it may be thicker elsewhere. It is predominantly fine-grained greenish-gray sandstone of the graywacke type, dark clay, and silt shale with minor amounts of conglomerate near the base. On the Siksikpuk River, where part of the formation is well exposed, it is 1,850 feet thick. Here it is characterized by a rhythmic alternation of fine-grained sandstone, silt shale, and clay shale. This alternation is not well developed in the formation along the Okpikruak River, although there is a suggestion of it.

The pelecypod *Aucella crassicollis* Keyserling,[5] which is characteristic of early lower Cretaceous (Neocomian) is found throughout this formation in the area of the type locality. The ammonite *Lytoceras* sp. has also been collected in the Siksikpuk River area. In the Nimiuktuk-Kugururok Rivers area on the south side of the De Long Mountains *Aucella okensis* Pavlow and *Aucella crassa* Pavlow have been collected. These

[5] Identification of macrofossils from the Okpikruak and Torok formations have been made by Dr. Ralph W. Imlay.

forms are characteristic of the very earliest Lower Cretaceous and would presumably mark a zone lower than that of *Aucella crassicollis* Keyserling.

TOROK FORMATION (NEW)

The type locality of the Torok formation (new) is Torok Creek, a tributary to the Chandler River in the vicinity of Castle Mountain. At Castle Mountain the Torok formation in the lower part comprises 2,000 feet of dark silt and clay shale with limestone concretions, and in the upper part about 8,500 feet of dark shale and marine conglomerate and sandstone of graywacke type. In exposures on the Chandler and Kiruktagiak Rivers, in the vicinity of Tuktu Bluff about 11 miles north of Castle Mountain, the Torok formation in the upper part consists of 4,500 feet of dark clay and silt shale, which includes 500 feet of sandstone and some conglomerate, and in the lower part, of 1,500 feet of dark silt and clay shale. Thus at Tuktu Bluff the Torok formation is 6,000 feet thick as compared with 10,500 feet at Castle Mountain.

The Torok formation is widely exposed in an east-west belt in the Southern Foothills section of the Arctic Foothills province. This belt is characterized topographically by irregular, isolated hills and ridges of sandstone and conglomerate, which rise above low-lying areas of little relief developed on the shale. Structurally, many of these isolated hills, such as Castle Mountain and Fortress Mountain, are synclines. At most places the Torok formation overlies the Okpikruak formation, but at one place has been found overlying Triassic rocks, indicating warping and erosion of the Okpikruak formation and Jurassic rocks in post-Okpikruak time. The degree of angular unconformity is unknown, as the contact is poorly exposed.

The fauna of the Torok formation is very scarce but includes some characteristic Aptian and early Albian forms. There are a few species of *Inoceramus*, *Beudanticeras* sp., *Cleoniceras* sp., *Lemuroceras* sp., *Lemuroceras* cf. *L. belli* McLearn, *Lemuroceras* cf. *L. aburense* Spath, and *Aucellina* cf. *A. dowlingi*. The ammonite *Cleoniceras* sp. also ranges into the overlying Tuktu

TABLE 1.—COMPARISON OF PAST AND PRESENT STRATIGRAPHIC NOMENCLATURE OF THE CRETACEOUS AND TERTIARY OF NORTHERN ALASKA

Schrader, 1902	Smith and Mertie, 1930	Gryc, Patton, and Payne, 1951				
Goobic (Gubik) sands	Quaternary	Quaternary	Gubik formation			
Tertiary Colville series	Tertiary	Tertiary	Sagavanirktok formation*			
	Upper Cretaceous series	Cretaceous	Upper	Colville group	Prince Creek formation (nonmarine)	Schrader Bluff formation (marine)
Upper Cretaceous Nanushuk series			Lower ?	Nanushuk group	Chandler formation (nonmarine)	Umiat formation (marine)
Lower Cretaceous Anaktoovuk (Anaktuvuk) series	Lower Cretaceous series		Lower	Torok formation		
				Okpikruak formation		

* Sagavanirktok formation is not equivalent to rocks previously called Tertiary and is not believed to be present in areas studied before 1944.

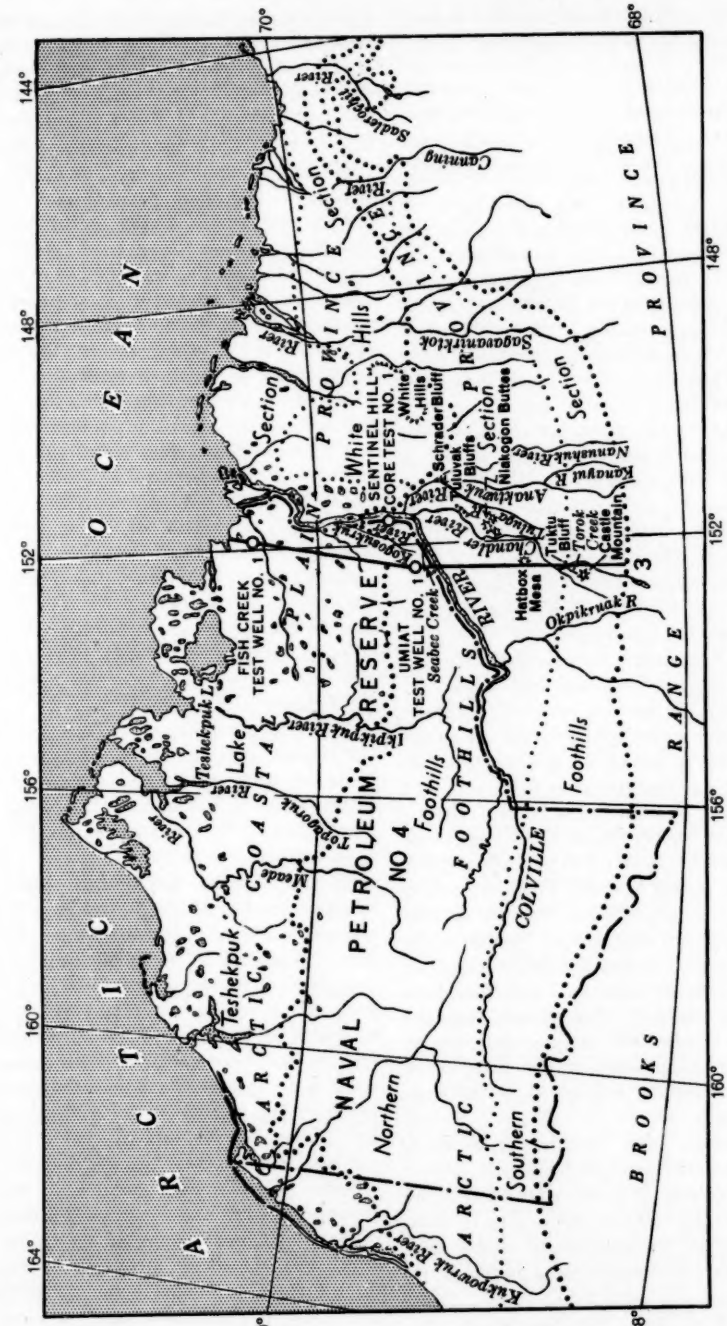


FIG. 1.—Index map of northern Alaska showing location of Fig. 3.

member of the Umiat formation. Arenaceous Foraminifera dominate the microfaunal assemblage.

Lower Cretaceous and Lower (?) Cretaceous

NANUSHUK GROUP (REDEFINED)

The Nanushuk "series" was named by Schrader[6] from the Nanushuk River which joins the Anaktuvuk River at about the midpoint of the type section. The type section was described by Schrader as the belt of rocks beginning 5 miles north of the junction of the Colville and Anaktuvuk Rivers and extending south for 30 miles. These rocks were described as sandstone, limestone, shale, quartzite, chert, black slate, and coal. Schrader[7] states that the series is best exposed "in the north (northeast) bank of the Anaktuvuk about 5 miles above the mouth of Tuluga River." This exposure is redescribed here as the type locality of the Schrader Bluff formation (new) of the Colville group (redefined). It is now apparent that rocks described by Schrader as the Nanushuk "series" of Upper Cretaceous age included beds of both Upper and Lower Cretaceous age and possibly older.

The name Nanushuk is here applied to a group of rocks of Lower Cretaceous and Lower (?) Cretaceous age. These are exposed along the Nanushuk River where the river cuts across the Arctic Foothills province of northern Alaska. Rocks of this group are known to crop out throughout the foothills north of the Brooks Range from the Sagavanirktok River west as far as the Kukpowruk River. The contact between the Nanushuk group and the Torok formation is believed to be gradational, but the contact zone generally is not well exposed because of the nonresistant nature of the Torok formation. In the Nanushuk River area the Torok formation appears to dip regionally more steeply than the Nanushuk group, but this is apparently due to a difference in competence. In the Kukpowruk River area the contact appears to be lithologically gradational.

The Nanushuk group includes shale, sandstone, conglomerate, and coal beds with little or no bentonite or tuff. It is estimated to be 5,750 feet thick in the outcrop area, but it thins slightly northward. Nonmarine and marine sedimentary rocks intertongue, as a result of repeated marine transgressions and regressions in Nanushuk time. Thus the Nanushuk group includes two intertonguing formations—the Chandler (nonmarine), which tongues into the Umiat (marine) to the north. Fig. 3 shows the relationship of the formations, members, and tongues.

Umiat formation (new).—The Umiat formation of the Nanushuk group is named from the marine part of the section below 750 feet in Umiat Test Well No. 1. (See Fig. 3.) In the vicinity of Umiat the inshore facies of the formation consists of relatively clean sandstone that grades northeast through argillaceous sandstone into shale of the offshore facies. The formation is estimated to be about 5,000 feet thick; the lower part is marine shale similar to shale of the Torok formation, which it overlies. Its fauna is almost exclusively mollusks and arenaceous Foraminifera. The lower part of the Umiat formation is Lower Cretaceous (mid-Albian), as determined from the scarce but distinctive mollusks. The upper part of the Umiat formation is probably also Lower Cretaceous (upper Albian), but the fossil data are inconclusive. The Foraminifera show a marked resemblance to those of the Ashville formation of Canada. The Umiat formation has been divided into two members—the Tuktu and the Topagoruk.

The Tuktu member is the basal member of the Umiat formation. Its type locality is on the Chandler River where this river cuts through Tuktu Bluff, a continuous south-facing escarpment that can be traced for many miles. At the type locality the member is about 1,000 feet thick and underlies the Hatbox tongue of the Chandler formation (see below). Here it consists almost entirely of marine sandstone. Northward from Tuktu Bluff to Umiat the member thickens progressively to about 2,500 feet and includes part of the marine equivalent of the Hatbox tongue of the Chandler formation, as this tongue changes to a marine facies. The characteristic fossil is an undescribed Lower Cretaceous *Inoceramus*. The ammonite *Cleoniceras* ranges from the Torok formation into the Tuktu member of the Umiat formation. The base of the Tuktu member coincides with the base of the Umiat formation and the base of the Nanushuk group.

The Topagoruk member of the Umiat formation is named from the section in Topagoruk Test Well No. 1, from 50 to about 3,100 feet. The top 1,000 feet includes nonmarine units of the Niakogon tongue of the Chandler formation and

[6] SCHRADER, F. C., *A reconnaissance in northern Alaska*. U. S. Geol. Surv. Prof. Pap. **20**: 79. 1904.
[7] SCHRADER, F. C., Idem.

consists of coal, shale, sandstone, and minor amounts of ironstone. The bottom 2,100 feet is entirely marine clay shale, silt shale, silt, and sandstone. Fossils found in this member are Foraminifera, the scaphopod *Laevidentalium*, and *Inoceramus* prisms. It is suggested that these fossils are of Lower Cretaceous age but this is not definitely established. The Topagoruk member thickens southward and intertongues with the Hatbox and Niakogon tongues of the Chandler formation. In much of the outcrop belt the Topagoruk member is represented by a marine sandstone which contains a diagnostic undescribed *Inoceramus* and other pelecypods.

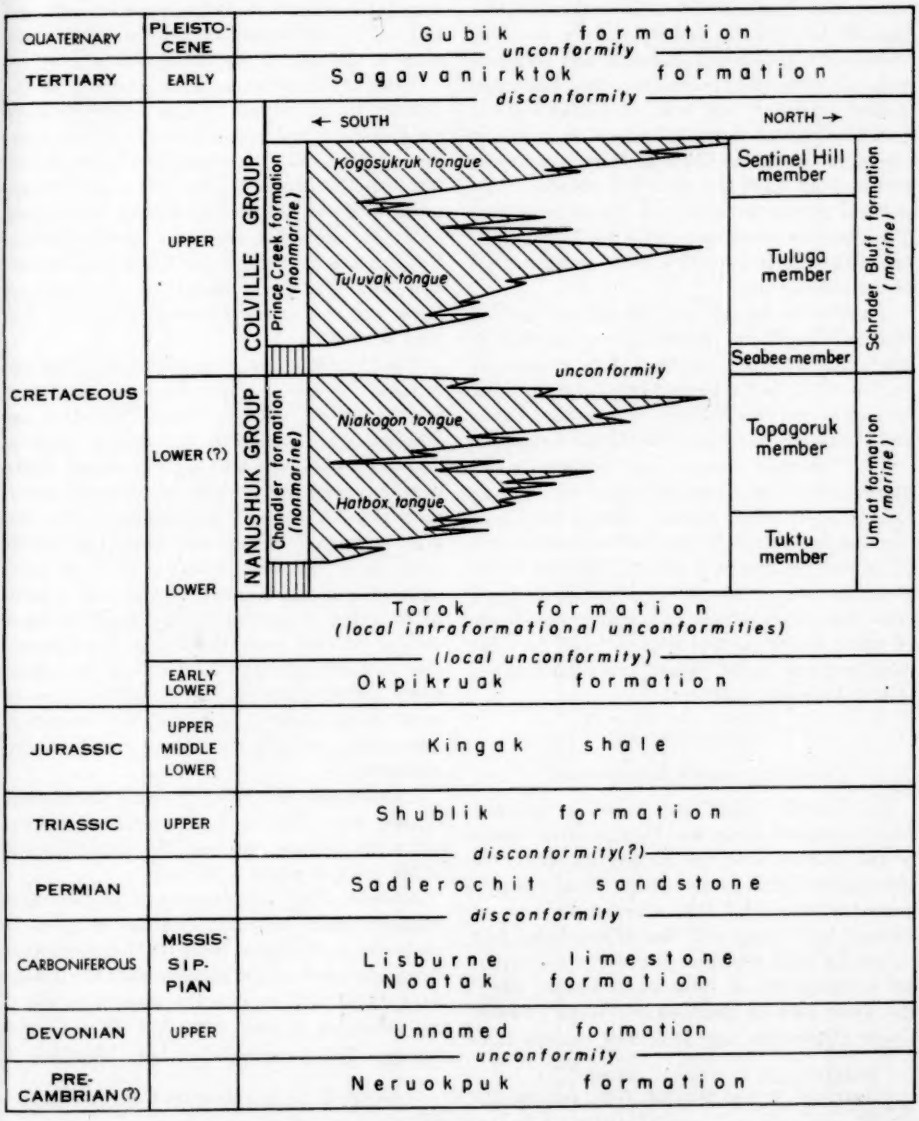


FIG. 2.—Diagrammatic columnar section of the Arctic slope of northern Alaska.

Chandler formation (new).—The Chandler formation (nonmarine) is exposed in the Northern Foothills section of the Arctic Foothills province of northern Alaska. It is the age equivalent of the Umiat formation, with which it intertongues northward in two major tongues (named) and several minor tongues (unnamed). Its type locality is on the Chandler River where the river crosses the Northern Foothills section. Lithologically most of the formation in the southern exposures is nonmarine sandstone and conglomerate. To the north it grades into shale with interbedded sandstone and coal; it contains a few fresh- to brackish-water mollusks in its northerly exposures. Along the Chandler River the formation is about 4,700 feet thick but includes minor units of marine strata of the Umiat formation. The Chandler formation overlies the Tuktu member of the Umiat formation in the southern part of the outcrop area.

The Hatbox tongue (new) at its type locality, Hatbox Mesa in the Chandler River drainage, is approximately 3,000 feet thick and wedges out northward. It is the lower part of the Chandler formation and lies between the marine Tuktu and Topagoruk members of the Umiat formation.

The Niakogon tongue (new) represents the upper part of the Chandler formation. Its type locality is Niakogon Buttes, between the Chandler and Anaktuvuk Rivers. In the southern part of its outcrop area it is about 1,700 feet thick; it wedges out northward. A persistent conglomerate bed, characterized by a greater percentage of white quartz pebbles than is found in other conglomerates in the region, forms the top bed of the Niakogon tongue.

Upper Cretaceous

COLVILLE GROUP (REDEFINED)

The Colville "series" was named by Schrader from exposures along the Colville River north of the junction with the Anaktuvuk River. On the basis of lithology and scanty floral evidence Schrader[8] concluded that these rocks were of Tertiary age. Smith and Mertie[9] concluded that "from the fossil evidence obtained in the apparent continuation of these rocks farther west" the lower part of the Colville "series" was of Upper Cretaceous age. It is now evident from microfaunal and macrofaunal evidence that these rocks are all of Upper Cretaceous age. The exposure on the west side of the Colville River 1 mile north of the 70th parallel was considered to be Tertiary by Smith and Mertie[10]. It is now believed that this exposure is of the same age as the Gubik formation, which is Pleistocene. This is apparently substantiated by the lack of any Tertiary beds in the many core tests and test wells in the Barrow-Simpson and Fish Creek areas to the west of the Colville River.

The Colville series is here redefined as the Colville group, applied to type exposures along the Colville River from approximately the junction with Prince Creek east and north to the 70th parallel. Rocks of this group are well exposed in river cuts; on the Colville River these cuts form bluffs that are nearly continuous from Umiat north to Ocean Point. These rocks extend west to about the longitude of the Ikpikpuk River and east to the Canning River, and perhaps beyond.

The Colville group is separated from the underlying Nanushuk group by a major unconformity. Rocks of lower Upper Cretaceous age (Cenomanian) appear to be missing. Beds of middle Upper Cretaceous age (Turonian) in the Colville group overlie beds of probable uppermost Lower Cretaceous age (Albian) in the Nanushuk group. The basal member of the Colville group is a distinctive unit consisting of black shale with limestone interbeds that can be readily identified in the field. The Colville group is divided into the nonmarine Prince Creek formation and the marine Schrader Bluff formation, which are approximately of equivalent age. In most of the outcrop belt the two formations intertongue and are not always readily distinguishable.

Lithologically the group includes clastic rocks ranging from shale to conglomerate, limestone, low grade oil shale, and coal. The total thickness of the group is about 5,200 feet.

Schrader Bluff formation (new).—The name Schrader Bluff formation (marine) is given to exposures at Schrader Bluff on the Anaktuvuk River just south of the junction with the Tuluga River. This bluff exposes the three members of the formation in over 3,000 feet of continuous outcrop. The formation has been identified in

[8] SCHRADER, F. C., Op. cit.: 81–83.
[9] SMITH, P. S., and MERTIE, J. B., JR., op. cit.: 232–233.
[10] SMITH, P. S., and MERTIE, J. B., JR., op. cit.: 235.

NORTH FRONT OF BROOKS RANGE
TUKTU BLUFF
VERTICAL SCALE IN FEET
4000
3000
2000
1000
0
COLVILLE GROUP
PRINCE CREEK FORMATION (Nonmarine)
NANUSHUK GROUP
CHANDLER FORMATION (Nonmarine)
TOROK FORMATION
UMIAT TEST WELL NO 1
SENTINEL HILL CORE TEST NO 1
KOGOSUKRUK TONGUE
SENTINEL HILL MEMBER
SCHRADER BLUFF FORMATION (Marine)
TULUGA MEMBER
SEABEE MEMBER
TOPAGORUK MEMBER
UMIAT FORMATION (Marine)
TUKTU MEMBER
Part of Topagoruk member probably missing.
Umiat anticline may have been growing in Topagoruk time.
FISH CREEK TEST WELL NO 1
ARCTIC COAST
NORTH
HORIZONTAL SCALE
0 5 10 20 30 40 MILES
NONMARINE SEDIMENTS
EXPLANATION
MARINE SEDIMENTS
INLAND FACIES
(Channel and floodplain deposits, possibly including alluvial fan material)
COASTAL FACIES
(Deposited in largely inundated belt of fresh- to brackish-water barred basins—marshes, bays, lagoons, and lakes. Includes deltaic deposits)
INSHORE FACIES
(Beach, bar, and near-shore deposits in general)
OFFSHORE FACIES
(Deposited on the part of the sea bottom that lies beyond the reach of most winnowing agencies)
Consists primarily of gray to yellow, well-rounded sandstone and conglomerate, although the beds are massive and persistent, large-scale cross bedding and lenticularity of textural types are common within beds. Many beds are cemented by calcite. Coal beds are few, and fossils remains are absent.
Consists primarily of fine grained, well-bedded sediments, shale and fine sandstone, but contains lenses of coarser sandstone and conglomerate which are highly cross bedded and probably represent channel fills. Beds of coal (lignite) common are characteristic but not present in all areas. Fossils are of fresh- and brackish-water types, and are limited to thin, widely separated zones, which formed together with coal in barred basins. The presence of these beds is a criterion for differentiating the Coastal facies from the Offshore facies, in which the permafrost, carbonaceous material, and fossils are rare or absent in the sandstone, shale, and silts. Also, the microfossils in the clay shales tend to be more abundant as to individuals (not species) than in the Offshore facies, probably because of the greater abundance of food in the shallower water

well cores from the Umiat, Fish Creek, Sentinel Hill, and Cape Simpson areas. North of Umiat the Schrader Bluff formation is bounded below by the Umiat formation, and in the Umiat area and to the south by the Niakogon tongue of the Chandler formation.

Lithologically it is similar to the Umiat formation, consisting largely of marine sandstone to the south and shale to the north, but it has a much larger percentage of bentonite and tuff, which increases upward through the formation. At Fish Creek Test Well No. 1 it is 2,600 feet thick.

The Schrader Bluff formation contains more megafossils, mostly mollusks, than the Umiat formation. The characteristic megafossils are species of *Inoceramus* and *Scaphites*. Foraminifera are somewhat rarer than in the Umiat formation, but local zones of planktonic forms are present.

The Seabee member is the lowest unit of the Schrader Bluff formation. In the outcrop area it is bounded below by the Niakogon tongue of the Chandler formation. The top part of the Seabee member contains a very distinctive 150-foot unit of fossiliferous paper shale, which is a low-grade oil shale and contains a characteristic fauna. Index fossils are *Scaphites delicatulus* Warren, *Watinoceras* n. sp., *Borissjakoceras* n. sp., and *Inoceramus labiatus* Schlotheim, which indicate that this unit is the equivalent of the Greenhorn limestone of Upper Cretaceous age of the western interior United States. The member is well exposed along a tributary of the Colville River, Seabee Creek, for which it is named. It is also well exposed along Maybe Creek, a tributary of the Ikpikpuk River. The Seabee member is 450 feet thick in the type locality.

The Tuluga member is named from the Tuluga River, which enters the Anaktuvuk River at the north end of Schrader Bluff. Schrader Bluff is the best exposure of this member and is its type locality. The member is also well exposed on the Chandler River near the confluence with the Ayiyak River and on the Colville River in the Umiat area. The maximum thickness is estimated to be 2,200 feet in the outcrop belt, but this thickness includes minor units of the Tuluvak tongue of the Prince Creek formation. In Fish Creek Test Well No. 1, from 1,195 to 2,350 feet, this member is almost entirely marine except for one thin coal bed and associated sandstone.

Lithologically the Tuluga member is distinguished by abundant bentonite and tuff interbedded with a light-colored sandstone, and shale. The Tuluga member contains the largest number of individuals and species of macrofossils of any unit in the Cretaceous of northern Alaska. Fossils are commonly distributed throughout sandstone zones a few hundred feet thick. The diagnostic macrofossils are *Inoceramus lundbreckensis* McLearn and an undescribed *Scaphites*.

The Sentinel Hill member is named from the section in Sentinel Hill Core Test No. 1 in which a little over 1,100 feet of marine beds of this member and nonmarine beds of the Kogosukruk member of the Prince Creek formation were penetrated. In the outcrop belt along the Colville River equivalent intertonguing marine and nonmarine beds total 2,340 feet.

Lithologically the Sentinel Hill member is characterized by volcanic glass shards, abundant bentonite, and tuff. In outcrop the beds are less consolidated than the underlying members. Faunally this member is distinguished by abundant radiolaria, fish bones, and diagnostic Foraminifera. Macrofossils are rare and consist of long-ranging generalized types of pelecypods.

Prince Creek formation (*new*).—The Prince Creek formation of the Colville group includes all the nonmarine beds above the top of the Niakogon tongue of the Chandler formation and intertongues with the Schrader Bluff formation. The type locality is Prince Creek, a tributary to the Colville River. The Prince Creek formation, like the Chandler formation, is made up of sandstone, conglomerate, shale, and coal, but contains considerably more bentonite and tuff than does the Chandler formation. Its fauna consists of a few fresh- to brackish-water mollusks. The Prince Creek formation has been separated into two major tongues.

The Tuluvak tongue, the lower part of the Prince Creek formation, is best exposed in the Tuluvak Bluffs on the Chandler River where it is 1,200 feet thick. It overlies the Seabee member (marine) of the Schrader Bluff formation.

The Kogosukruk tongue is the age equivalent of the Sentinel Hill member of the Schrader Bluff formation. It is named from the Kogosukruk River, along which it is well exposed. Equally good if not better exposures which are more readily accessible are along the Colville River from near its confluence with the Anaktuvuk

River to Ocean Point just north of the 70th parallel. The total thickness along the Colville is 2,340 feet but this includes marine units of the Sentinel Hill member of the Schrader Bluff formation.

The Kogosukruk tongue is distinguished from the older units by its poor consolidation, finer texture and somewhat brighter colors. It consists largely of clay, silt, and shale. Bony coal and bentonitic beds are common. Sandstone is rare, and only one conglomerate, 15 feet thick, has been mapped. Macrofossils are very rare and consist of fresh-water and brackish-water pelecypods and gastropods.

In the outcrop belt this tongue overlies the Tuluga member of the Schrader Bluff formation and is covered by a thin mantle of the Gubik (Quaternary) formation.

TERTIARY ROCKS

Sagavanirktok formation (new)

The Sagavanirktok formation crops out in the Franklin Bluffs, its type locality, along the lower part of the Sagavanirktok River and is also well exposed in the White Hills area. It consists mainly of red-bed-type, poorly consolidated siltstone, sandstone, conglomerate, and lignite. No fauna has been found, but the formation does contain an early Tertiary flora. The Sagavanirktok formation is structurally conformable with the underlying Colville group and no large erosional break is indicated by the field data. The rocks here named the Sagavanirktok formation have not been previously mapped or described. They apparently do not crop out west of the Itkillik River and are not definitely known in the Canning River area. Thus the formation lies in an area that was unmapped and unexplored by geologists before 1944

QUATERNARY ROCKS

Pleistocene

GUBIK FORMATION

The Gubik formation of Pleistocene age mantles the older rocks in much of the Arctic Coastal Plain of northern Alaska. The name Gubik sand was first applied by Schrader[11] to a "surficial deposit of brownish sand or loam about 10 to 15 feet in thickness" which is exposed along the Colville River in the Coastal Plain province. The name is from the Eskimo name of the Colville River. Leffingwell[12] points out that the Eskimo name for the lower river is Kupik or "big river." Gubik, now the accepted spelling, is apparently a misspelling of Kupik.

The Gubik formation, as here redefined, ranges in thickness from a few feet to 150 feet, but in most exposures is 10 to 30 feet thick. It is largely marine and consists predominantly of loosely consolidated, cross-bedded, brown or buff gravel, sand, silt, and clay. The microfauna is somewhat similar to recent faunas and is more diversified than any of the older microfaunas of northern Alaska. The Gubik fauna differs from living Arctic faunas in that no pelagic forms have been found.

The bluffs along the west bank of the Colville River from the mouth of the Anaktuvuk River to Ocean Point expose the Gubik formation lying unconformably on the upper 1,500 feet of the Colville group. This is the original type locality as defined by Schrader[13]. A maximum thickness of 30 feet is exposed along the Colville River, but a thickness of 150 feet has been mapped on the Kikiakrorak River, 15 airline miles upstream from its confluence with the Colville River.

[11] SCHRADER, F. C., op. cit.: 93.
[12] LEFFINGWELL, E. DE K., *The Canning River region, northern Alaska*. U. S. Geol. Surv. Prof. Pap. **109**: 95, 109. 1919.
[13] SCHRADER, F. C., op. cit.: 93.

ZOOLOGY.—*A new subgenus of* Diaptomus (*Copepoda: Calanoida*), *including an Asiatic species and a new species from Alaska.*

MILDRED STRATTON WILSON, Arctic Health Research Center, Public Health Service, Federal Security Agency, Anchorage, Alaska. (Communicated by F. A. Chace, Jr.)

This paper is part of a projected survey of the fresh-water Copepoda of Alaska. It includes the description of a new species of *Diaptomus* that has zoogeographical importance because of its close relationship to one from the Asiatic portion of the U. S. S. R. This latter species (*D. rylovi* Smirnov, 1930) has been assigned by Kiefer (1938a) to his genus *Neutrodiaptomus*. Since it and the new Alaskan species exhibit distinct differences from all the other members of this group, a new division is proposed to include them. This is given the status of subgenus, as I agree with Light that the structural range of variation among the species of *Diaptomus* (sensu lato) is not great enough to allow the full rank of genus to most of the subdivisions of the so-called Diaptominae proposed by Kiefer (1932, 1936a-d, 1937, 1938a-b) and himself (1938, 1939).

Family DIAPTOMIDAE

Genus **Diaptomus** Westwood

The broad definition of *Diaptomus* used here excludes only the species delegated by Kiefer to genera of the Paradiaptominae and to *Acanthodiaptomus*, which is characterized by features common to his two subfamilies. Such a definition must include *Hemidiaptomus* Sars, 1903, because it is naturally a part of the large series of subgenera into which it is possible to divide *Diaptomus*. Kiefer's studies have drawn attention to the highly significant, but hitherto largely neglected characters of the left exopod of the male fifth leg. The structure in *Hemidiaptomus* of this and of other appendages of systematic importance, do not depart from the basic patterns found in *Diaptomus*.

One of the remainder of Kiefer's groups, *Psychrodiaptomus* (1938b), is a synonym of *Leptodiaptomus* Light. These names were both proposed in 1938, but the publication date of *Leptodiaptomus*, March 9, precedes that of *Psychrodiaptomus*, April 20.

It is felt that detailed reexamination of many species, particularly of those of North America, is needed before an evaluation of Kiefer's system of classification is possible. Therefore, a rediagnosis of *Diaptomus* is deferred for the present.

Nordodiaptomus, n. subg.

Subgenotype.—*Diaptomus siberiensis*, new name for *Diaptomus rylovi* Smirnov, 1930.

Diagnosis.—Of moderate size, length of females between 1.6 and 2.4 mm; of males between 1.4 and 1.7 mm. Metasome without bizarre protrusions, the wings of last segment in female only moderately developed; last segment distinct in male. Urosome of female with 3 well-defined segments, the genital a little asymmetrical, the sensilla not grossly developed; urosome of male asymmetrical or not.

Antennules short in both sexes, only reaching to near the end of the metasome; that of the female with a stout, very elongate seta on the first segment, and with segments 11 and 13 to 19 usually with 2 setae. The left antennule of the male differing from that of the female in having the seta of segment 1 not so well developed and only a few of segments 13 to 19 with more than 1 seta. Right antennule of male with the spines of segments 8 and 12 not enlarged, those of 10, 11 and 13 much enlarged, with dissected ends, that of 13 not reaching beyond segment 14; segments 14–16 very tumid, 14 without a process or spine; segments 15–16 with short cuticular processes; the antepenultimate segment without armature of any kind.

Maxilliped not enlarged; the endopod about half the length of the basipod, its setae slender and nonprehensile.

Outer spines of the exopods of legs 1–4 normal, those of leg 1 not at all enlarged. Leg 2 of female lacking the dorsal cuticular lappet (Schmeil's organ) of the second endopod segment; absent or not in the male.

Fifth leg of female with exopod symmetrical, the third segment distinct, its setae and that of the second segment not elongate but very stout and subequal to one another. The endopod usually shorter than the first exopod segment, normally with a single, subapical, more or less well developed spiniform seta. The endopod and its armature symmetrical or not, the whole ramus sometimes subject to considerable variation within a single population.

Fifth leg of male without bizarre armature. The right leg having the apical claw very elongate, its length about equal to that of the rest of the ramus; the lateral spine of exopod 2 stout and near the terminus of the segment; posterior face of exopod 1 with very small but heavy lamellae. Exopod 2 with or without inner cuticular spine. Both pads of the distal segment of the left exopod well defined, about equal in length, the distal narrower than the other, posteromedial in position; the proximal bulging a little medially, and with a narrowed portion extended across the top of the segment on the anterior side; both pads armed conspicuously with slender to stout hairs. The processes closely set, both distally directed; the distal short, its length not more than one-half that of the outer margin of the segment, digitiform, continuous with but more or less demarcated from the segment, with or without spinules on its inner margin; the proximal process a subterminal, stout, curving spine, reaching to the end of the other process or beyond, armed laterally with spinules. Endopods not grossly developed.

Included species: *Diaptomus siberiensis*, n. name; *Diaptomus alaskaensis*, n. sp.

Diaptomus siberiensis, n. name

Diaptomus rylovi Smirnov, 1930, pp. 79–82, fig. 1; 1931, pp. 627–634, figs. 12–21; Kiefer, 1932, p. 478. *Neutrodiaptomus rylovi* Kiefer, 1938a, p. 46.

The description given in German by Smirnov (1931) has been largely used in this study. The diagnostic characters of *D. siberiensis* are given herein in the section in which it is compared to the new Alaskan species.

Occurrence.—The type locality is a small lake at Bonmak, on the bank of the River Zeya, in the Amur region of southeastern Asiatic U. S. S. R. This is apparently in the area of the head waters of the River Zeya, which according to Berg (1938) lies in the Stanovoy mountain range. Smirnov does not give the altitude, but it appears to be in the secondary southern chain having peaks of relatively low elevation (1,400 meters). The species was also found in a collection from Kjusjur, toward Bulun, which is a little south of the delta of the Lena River on the Arctic coast. This is in tundra area where the subsoil is permanently frozen and superficially at least, represents a contrast to the mountain lake habitat of the Amur locality.

Variation.—Smirnov mentioned no variation in the specimens from the type locality, except for the division of the claw of the fifth leg in some males. In the Lena River specimens, the male was wholly typical, but the female was much smaller in size, 1.7 mm as opposed to the 2.4 mm of the Amur specimens, and had only one seta instead of two on the thirteenth segment of the antennule. The endopod of the fifth leg differed in being shorter, and in having its first segment longer than the second. No statement was made as to whether these variations characterized a single individual or several.

Nomenclature.—The specific name *rylovi* was used by Charin (1928) for a species of *Hemidiaptomus*. As pointed out above, this group exhibits no differences from other groups of *Diaptomus* sufficiently distinct enough to warrant other than subgeneric status; Charin's species should therefore be known as *Diaptomus* (*Hemidiaptomus*) *rylovi*. This necessitates the renaming of Smirnov's species; the name *siberiensis* is proposed as a geographic contrast to that of the related Alaskan species.

Diaptomus alaskaensis, n. sp.

Figs. 1–29

Specimens examined.—30 ♀ ♂, collected in a mountain top pool, Eagle Summit, on the Steese Highway between Fairbanks and Circle, Alaska; elevation 3,880 feet; July 4, 1947. Collector, Charles S. Wilson.

Types.—In the United States National Museum. Holotype male, no. 90711; allotype female, no. 90712.

Description.—Length of preserved specimens, middorsal line, female, about 1.65 mm; male, about 1.44 mm.

FEMALE

Metasome (Fig. 7).—Approximately twice the length of the urosome in middorsal line. In dorsal view, the greatest width occurring just behind the cephalic suture, tapering from there to the beginning of the second segment, beyond that of rather uniform width to the wings of the last segment which are a little expanded. The cephalic segment a little longer than segments 2–4 combined (proportions approximately 37:32); its suture distinct; the anterior portion roughly triangular in dorsal view. The last segment imperfectly separated by a short lateral suture, the wings well rounded at the sides, reaching posteriorly to about the middle of the

genital segment; the tips only slightly drawn out, the asymmetry not distinctly pronounced. Each side armed with two types of sensilla, that of the wing tip a small peglike seta; the other a shorter seta set on a small rounded tubercle and arising on the inner rounded portion of the wing (Fig. 10). The marginal hyaline area of the wing (demarcated in Fig. 11 by dotted lines) very narrow.

Urosome (Fig. 11).—All three segments distinct. Genital segment not markedly inflated, but noticeably asymmetrical; the left side with a gently rounding lobe above the middle; the anterior half of the right side produced into a large backwardly directed lobe, behind which laterally is another narrowly rounded area. Each side armed on the anterior lobe with a sensillum very like that of the inner lobe of the thoracic wing. The rest of the urosome symmetrical; the third segment longer than the second (proportions about 3:2); the caudal rami only a little longer than the third segment, their length about twice their greatest width; with hairs on the inner margins from near the proximal portion to the tip; caudal setae normal.

Most females of the sample were ovigerous; the eggs comparatively large and few in number (6 to 10).

Rostral filaments (Fig. 8) attenuated and very slender.

Antennule (Fig. 5).—Comparatively short, reaching to near the tips of the thoracic wings. The elongate seta of segment 1 (measured from its base) reaching to between the end of segment 11 and the middle of segment 12; very stout basally and throughout much of its length, arising from a well defined and large cuticular base. (In Fig. 5 for convenience in arrangement of drawings, this seta has been "pulled in" towards the body of the antennule; in all the preserved specimens, both before and after dissection, it is held out more or less perpendicular to the segment; the stoutness of the proximal portion suggests that this is the natural position in life.)

The number of setae on segments 1–10, 12 and 20–25 as usual: 3 on segment 2, 2 on 9 and 22–23, 5 on 25, 1 on the others. Segments 11 and 13–19 with 2 setae each. Aesthetes normal in distribution.

Maxilliped (Fig. 6).—First basal segment with all 4 lobes well developed, their setation normal; the distal seta of lobes 2–3 much longer than the others accompanying it, subequal to each other and to that of lobe 1; the four setae of the extended distal lobe all shorter than the longest seta of lobes 1–3, the proximal the shortest, the others subequal. Second basal segment a little shorter than segment 1, its distal seta the longer, about equal to the longest setae of lobes 1–3 of the second segment. The partially suppressed segment bearing two setae. The endopod about as long as basal segment 2, of five distinct segments, all of its setae slender and setiform, those of the inner side all shorter than the 3 terminal outer setae of the apical segment.

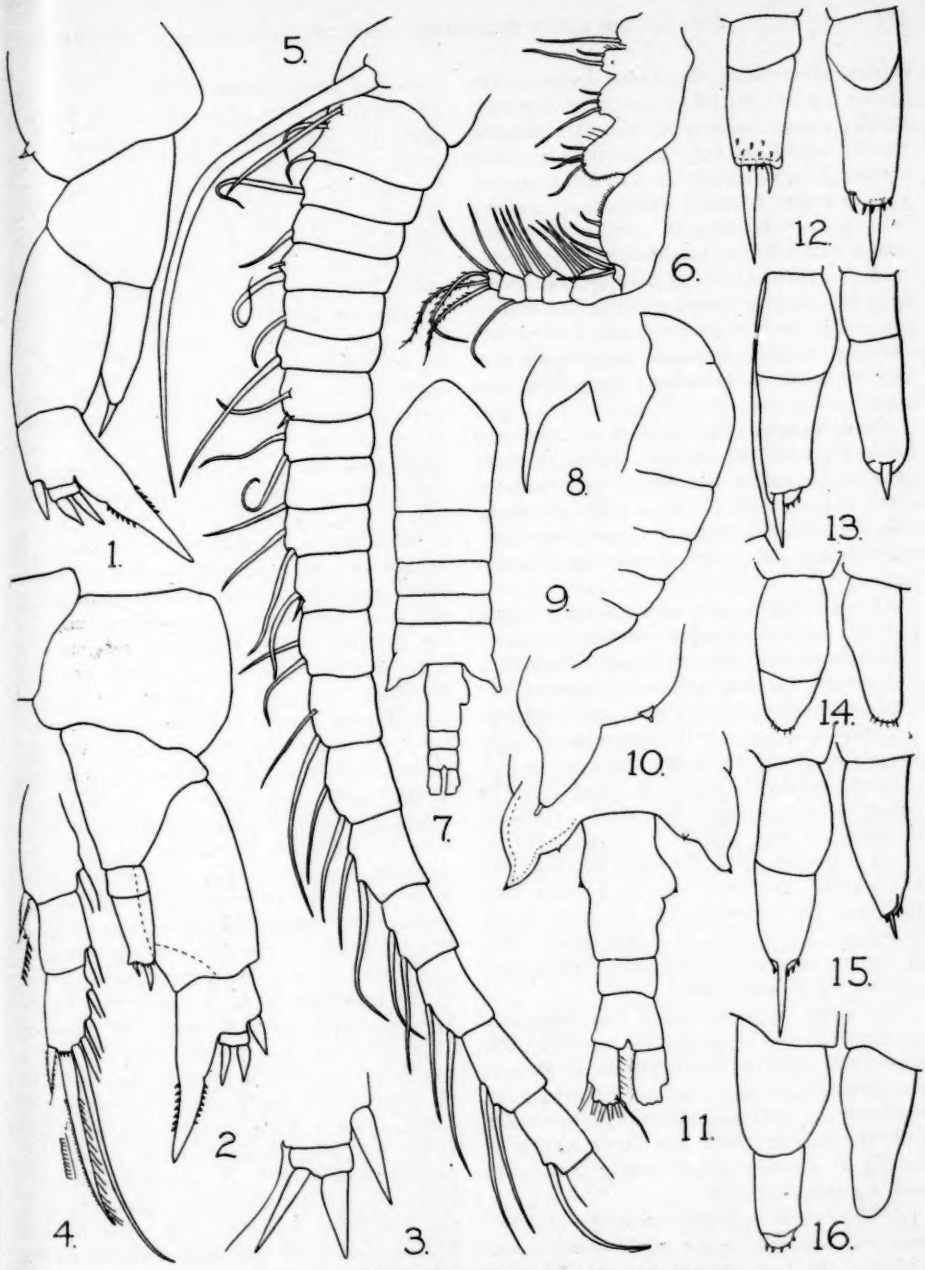
Leg 1 (Fig. 4).—The ventral surface of basipod 2 with a patch of long fine hairs on its outer portion just above the exopod, the remainder unarmed. Outer spines of exopod segments 1 and 3 only moderately stout; subequal to one another, that of segment 3 being only a little longer than that of 1 (approximate proportions 11:10); both tipped apically with a very slender sensory hair; their marginal spinules minute (see detail, Fig. 4), hardly distinguishable except at very high magnification. The spine of segment 1 reaching only to about the middle of the second segment, bent, with a resultant inner marginal notch proximally.

The elongate terminal spinelike seta of segment 3 stout, broader basally than the outer spine, its inner margin indented, bearing fine marginal hairs below the point of indentation; the outer margin, beginning at a corresponding point, armed with a very narrow, finely serrate flange (see detail, Fig. 4). The other setae of the segment all reaching considerably beyond the apex of this outer seta (proportional lengths, about 70:54). The outer margins of the exopod segments without hairs.

Leg 2.—The second segment of the endopod lacking a cuticular lobe on the dorsal face.

Leg 5 (Figs. 1 and 2).—The posterior side of the first basal segment tumid; the sensillum short and spinelike, mounted on a small tubercle. Second basal segment not tumid, considerably prolonged on the anteromedial side to the point of attachment of the endopod (Fig. 2); no sensory hair apparent, a cuticular depression observed in the place of its normal location on one specimen.

The exopod (to tip of claw) only a little longer along its inner margin than the basipod. The inner margin of the first segment roughly about two-thirds of the length of the outer (proportions 25:35); its width about three-fourths of the length of the inner and about one-half of that



FIGS. 1–16.—*Diaptomus alaskaensis*, n. sp., female

1–3, Leg 5: 1, Left side, posterior view, specimen no. 7; 2, left, anterior view, specimen no. 2; 3, exopod setae, specimen no. 5. 4, Leg 1, exopod. 5, Antennule, segments 1–20. 6, Maxilliped. 7, Dorsal outline of body. 8, Rostral filament. 9, Lateral outline of body. 10, Detail metasome wing and sensilla. 11, Last metasome segment and urosome. 12–16, Leg 5, endopods: 12, Specimen no. 2, anterior view; 13, specimen no. 6, posterior; 14, specimen no. 8, posterior; 15, specimen no. 7, posterior; 16, specimen no, 3, posterior.

of the outer margin. The inner margin of the second segment (to tip of claw) a little shorter than the outer margin of the first segment (32:35), about one-third longer than the inner margin; its greatest width a little less than one-half its length. Claw moderately stout, curving inwards on both margins a little above the middle, with a distinct notch on the outer margin; armed on both sides with 6–10 spinules; some specimens showing a faint crosswise line of division at the position of the notch. Lateral seta stout and spiniform, unarmed, a little more than half the length of the outer margin of the segment.

Third segment (Fig. 3) distinct, short and broad, its width almost twice the length of its outer margin which is a little longer than the inner. The outer seta similar in length and stoutness to that of the second segment, the inner more slender and a little longer; both unornamented.

The endopods of a pair asymmetrical in length and in armature; showing extreme variability within the available sample. Usually 2-segmented and shorter than the first exopod segment; unarmed terminally or with a short spiniform seta.

Variation in leg 5.—Measurements of eight specimens showed slight differences in the proportional lengths and widths of the exopod. The greater number attained that shown in Fig. 1, in which the inner margin of exopod 2 (to tip of claw) is subequal to the outer margin of the first segment and about one-third longer than the inner. Two specimens had the inner margin of segment 2 proportionally a little shorter (Fig. 2), and in one specimen they were a little longer, approaching *D. siberiensis*.

The widths of exopod 1 and 2 in diaptomids are never precisely measurable, but even with allowances made for the differences in position and flattening of the mounted appendages by the cover slip, it is apparent that the specimens with the shorter claws (the inner margin of exopod 2) are also proportionally broader in both segments 1 and 2.

So far as could be judged, no significant difference was apparent in the relative length and width of the third exopod segment. There is some slight difference in the proportional strength of the setae from specimen to specimen, but the relation of the two to each other is rather constant.

The endopod is extremely variable, differing in each of the specimens studied. The differences are shown in Figs. 12 to 16, and in Table 1, where the total length is also compared to the length of the inner margin of the exopod. Of the eight examined, four have a terminal spiniform seta; one of these differs from the others in having in addition a small abortive seta (Fig. 12). The endopods also show an unusual asymmetry. This is evident in the relative lengths of the right and left ramus of a pair, the left being always the longer; this difference considerable in some specimens (Table 1, nos. 4 and 7); negligible in others (nos. 1 and 8). The asymmetry is further expressed in the relative lengths of the terminal setae, that of one side always longer than that of the other (Figs. 13 and 15). The spinule pattern of the terminal portions also differs (Figs. 12 and 16).

Variability in the endopod of the female in *Diaptomus* is not at all rare, but it is more commonly expressed in differences in segmentation, and small differences in proportional length of the endopod to the exopod. In subgenera in which 2 setae are normally present, one may sometimes be lacking. In general, the endopod is much more variable in the males of the genus, but in this species the opposite is true. As noted above, Smirnov found a geographical variation in the female of *D. siberiensis*. We do not, of course, know how variable that species is, as he gives no indication of whether he found the condition illustrated in Fig. 15 (Smirnov, 1931) to be true of one or several specimens. Actual comparisons between the two species as regards this variability is therefore not now possible.

The asymmetry of the endopod, as of the rest of the appendage, is an invariable rule in the male diaptomid, but it is usually not expressed in the other sex. Only in recent years has such a condition been noted in the fifth legs of females of certain south Asiatic groups (*Allodiaptomus* Kiefer, 1936a–b, *Mongolodiaptomus* Kiefer, 1937, 1938a) and some South American species (*D. azevedoi* Wright 1935, *D. paulistanus* Wright, 1937). Though this asymmetry appears to be a well established character, it may also be that in some cases so few specimens of a given species have been examined that what is actually anomalous has been described as normal. For my part, I should like to reserve judgment on the condition in *D. alaskaensis* until more individuals from both the type and other localities in which it may occur are available for study.

MALE

Metasome.—About one and a half times the length of the urosome. More slender than the female, the greatest width in dorsal view occurring at the middle of the cephalic segment, from there the whole body tapering gradually to the terminal part. The anterior portion of the cephalic segment somewhat narrowed, the rather broad triangular appearance of the female only indistinctly suggested. The last segment separated, its lateral tips not drawn out, but asymmetrical (Fig. 21), the left side straight, the right angular, its distal half directed inwards; each side armed at the lateral tip with a single sensillum, very small and spiniform, mounted on a tubercle having rather straight sides (Fig. 20), the tubercle of the right a little larger than that of the left side of the segment. The hyaline area as demarcated in Fig. 20.

Urosome (Fig. 21).—Not conspicuously asymmetrical. The genital segment with the right side a little inflated and irregular in outline; the left side with the lateral slit conspicuous, the backwardly produced proximal lobe not covering it; neither side with apparent sensillum. Segment 4 a little longer on the right than the left side, the other segments symmetrical. Caudal rami normal, with the inner margins hairy.

Rostral filaments.—Relatively as long as those of the female, but a little stouter throughout most of their length.

Antennule.—The right reaching to the end of the second urosomal segment, the left a little shorter; both relatively longer than those of the female. The left (Fig. 17) differing also from that of the female in having the seta of segment 1 not so enlarged or lengthened; stretched out it reaches from its base only to about the middle of the fourth segment. Setae of the second segment also unlike those of the female. The setal pattern differing in that only segments 11, 16 and 19 of the midportion of the antennule have 2 setae; the others with one each. In addition to that of segment 1, rather long setae found on segments 7, 9, and 14. Those of 7 and 9 subequal and a little longer than those of 1 and 14 which are also subequal to each other. The approximate proportions of these setae to one another are:

segment 1—41	segment 7—55
segment 14—40	segment 9—54

Aesthetes of normal distribution as in female.

The right antennule with segments 14–16 conspicuously swollen (Fig. 18). Spines of 8 and 12 not enlarged; those of segments 10–11 and 13 very stout; that of 10 not as long as the width of its segment; that of 11 longer, reaching to the middle of segment 13; that of 13 strongly bent distad, incompletely demarcated from the segment, a little stouter but scarcely longer than that of 11, reaching to the middle of segment 14; the tips of all 3 spines dissected as indicated in figure 19. Segments 15–16 each with short cuticular processes of similar size; modified setae, with subterminal lateral tongue-like processes (Fig. 18), accompanying them and the depressed process of segment 17, all subequal to one another. Antepenultimate segment without process or lamella. Setae of terminal segment all weakly developed.

Maxilliped and *leg 1* as in female. *Leg 2* also lacking a cuticular lobe on the dorsal face of the second segment of the endopod.

Leg 5 (Figs. 22–23).—The left leg a little more slender than that of the right side; reaching almost to the end of its second exopod segment.

Right leg: The outer portion of the first basal segment very tumid, overhanging the second segment considerably on the postero-lateral side; the inner side also expanded with a large distally directed hyaline lamella on the anterior face (Fig. 22); the sensillum a seta without apparent tubercular base, in a distal medial position on the dorsal side. The outer margin of the second

TABLE 1.—COMPARISON OF THE ENDOPODS OF LEG 5 IN EIGHT PARATYPE FEMALES OF DIAPTOMUS ALASKAENSIS

Specimen No.	Right endopod				Left endopod		
	Exopod 1 Inner margain	Total length	Number of segments	Armature	Total length	Number of segments	Armature
1	78μ	39μ	2	Spinules	42μ	2	Spinules
2	75	45	2	2 setae + spinules	57	2	2 setae + spinules
3	81	45	1	None	57	2	Spinules
4	81	42	2	Spinules	60	2	Spinules
5	75	36	2	None	45	2	Spinules
6	75	54	2	1 seta + spinules	66	2	1 seta + spinules
7	69	42	2	1 seta + spinules	57	2	1 seta + spinules
8	60	42	1	Terminal hairs	45	1	Terminal hairs

basal segment rounded, the hair at the distal fourth; the inner margin a little longer than the outer, prolonged a little to the point of attachment of the endopod; the medial portion somewhat expanded and having attached to its posterior face a hyaline membranous lamella that bulges upward.

Exopod (exclusive of claw) subequal in length to the basipod. The first segment having the length of its outer margin greater than that of the inner (proportions about 27:17) and about equal to its greatest width; ending in a distally directed, rounded lobe; on the posterior face, near the extreme distal margin, two small, rather heavily chitinized lamellae (Fig. 24), that near the outer edge V-shaped, the other having a thick, pointed edge that is produced a little beyond the inner distal corner of the segment and extended more or less toward the other as a bar. The second segment with both margins nearly straight; the inner a little less than twice the greatest width (relative proportions 40:25); the outer curving inwardly at the point of attachment of the lateral spine; the inner distal edge membranous and somewhat crenulated. This segment bearing the characteristically rounded, small, heavy lamella on the proximal inner edge of the posterior side; somewhat distad to this and very near the margin, a minute and thin cuticular spine. Lateral spine near the terminus of the segment, stout and long, a little longer than the outer margin of the segment above its base, coarsely dentate on its inner edge. Claw very long, its length about equal to that of the ramus, strongly curved beyond its middle, enlarged at its base, with a small tubercle on the anterior side (Fig. 22), dentate below this bulbous enlargement to near the tip; in some specimens a fine division into two parts noticeable near the middle of the claw.

Endopod a little shorter than the inner margin of the first segment of the exopod; 2-segmented, the first broadened basally and only about half the length of the distal segment.

Left leg: The first basal segment not expanded on the outer margin, but extended inwardly to a well rounded lamelliform edge; sensillum a minute, curved spinule, mounted on a small tubercle. The second segment having its outer margin shorter than the inner, concave at its center; the sensory hair at the distal fifth; the inner distal margin considerably prolonged medially to the point of attachment of the endopod; a distinct jog in its margin just in front of the middle.

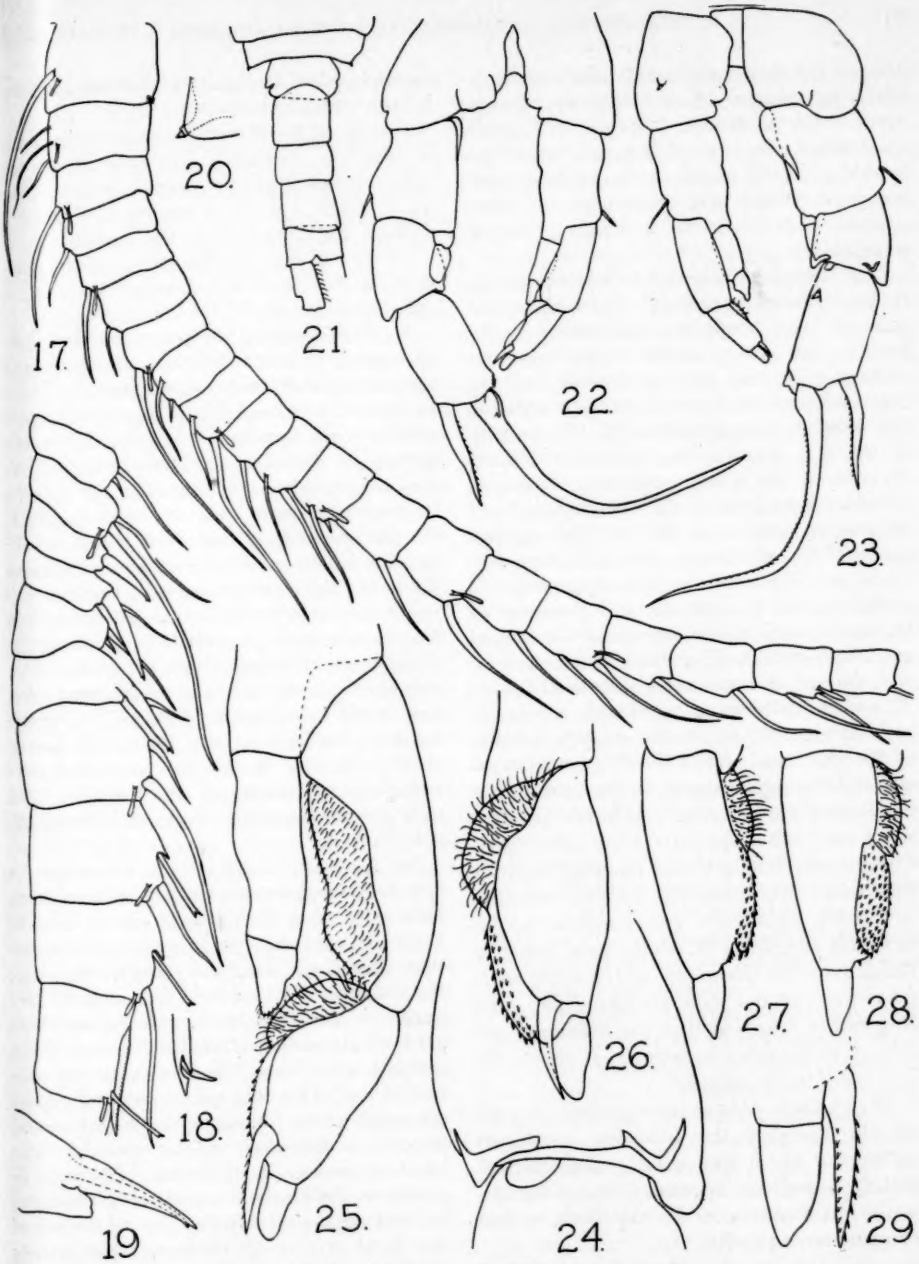
Exopod narrowed to about half the width of the basipod, its length along the outer margin somewhat less (about one-sixth). The first segment about two-thirds of the total length, provided on its anterior inner side (Fig. 25) with a narrow flattened pad armed with very short fine hairs. Both pads of the distal segment in a medial position, the proximal the more tumid, bulging a little on the anterior side with a narrowed portion carried across the proximal part of the segment so that it appears to fit tightly into the segmental suture (Fig. 26); on the posterior side only a small lengthwise portion of the pad visible (Figs. 27–28); armed with fine hairs that are longer than those of the pad of the first segment. The distal pad reduced in breadth, largely postero-medial in position, distally not reaching to the base of the terminal process; its apical portion sagging somewhat and forming a notch with the main body of the segment, as visible in posterior profile (Fig. 27); pad set with very short, stout hairs. On the margin of the segment between the apex of the pad and the inner base of the terminal process there may be 1–3 minute spinules, but these not always present.

The processes of the distal segment closely set (Fig. 29). The digitiform distal process demarcated from the segment, its length a little less than one-third that of the outer margin of the segment; very broad throughout most of its length, but its tip slightly drawn out; its inner margin without teeth. The proximal process spiniform, curving toward the terminal process and reaching to its apex or a very little beyond it; attached on the anterior side of the segment, distally directed; a little enlarged basally, the width at its middle about one-third that of the distal process; with coarse teeth on its inner margin, and a similar row on the posterior side near its outer edge.

Endopod reaching a little beyond the first exopod segment, 2-segmented, the distal segment about one-third the length of the other, with a few fine hairs on the apex.

COMPARISON OF D. SIBERIENSIS AND D. ALASKAENSIS

Smirnov's description of *D. siberiensis* is precise and detailed so that a fairly exact comparison of the two species can be made.



FIGS. 17–29.—*Diaptomus alaskaensis*, n. sp., male

17, Left antennule, segments 1–20. 18, Right antennule, segments 8–17, with detail of modified seta. 19, Right antennule, segment 13. 20, Detail, left metasome wing. 21, Last metasome segment and urosome. 22–29, Leg 5: 22, Anterior view; 23, posterior view; 24, detail lamellae, right exopod; 25, left exopod and endopod, anterior; 26, detail exopod 2, anteromedial view; 27, exopod 2, posterior; 28, exopod 2, posteromedial view; 29, exopod 2, detail of processes, posterior view.

He did not describe the maxilliped or leg 1, and the characters of these appendages given in the subgeneric diagnosis are from *D. alaskaensis*. No basic differences can be expected to occur in two such closely related species, so that only knowledge of minor specific differences is lacking for these appendages.

The resemblance between the two species is great. They appear to have the same general body form; the antennules of the females are alike; there is no apparent difference in the right antennules of the males, though those of the left side differ in the setation of some segments. Comparison of the fifth legs of the females is difficult because of the great variability found in certain characters of *D. alaskaensis*, and because it cannot be told whether or not those of *D. siberiensis* are also extremely variable. The form of the appendage is similar in the two species, and the setae of the second and third segments of the exopod are alike; certain differences which may be well defined and stable are discussed below. The male fifth legs are strikingly similar in general appearance, in the relative lengths of the two rami, and of the claw and lateral spine of the right exopod, in the form of the lamellae of the right leg, and in the arrangement and form of the pads of the left exopod. Careful observation shows some well-defined differences which coupled with the setation of the left antennule, were constant in the available sample of *D. alaskaensis*. Smirnov found that the characters of the male of *D. siberiensis* did not vary geographically, and this makes it appear that the males are not subject to the same variation that affects the females of the subgenus.

The two species have been herein separated on the basis of the following important differences which appear to be characters of stability, and are apparently carefully described by Smirnov for *D. siberiensis*, so that comparison is possible:

Rostral filaments short and stout in *siberiensis*; slender and attenuated in *alaskaensis*.

Left antennule of male with 2 setae on segments 11 and 18 in *siberiensis*; with 2 setae on segments 11, 16 and 19 in *alaskaensis*.

Leg 2 with a cuticular lappet on segment 2 of the endopod of the male in *siberiensis*; lacking in both sexes in *alaskaensis*.

Urosome of female having the genital segment in *siberiensis* apparently less produced on the right side than that of *alaskaensis* and with segments 2 and 3 equal in length; in *alaskaensis* segment 2 is much shorter than segment 3.

Urosome of male in *siberiensis* is wholly symmetrical; in *alaskaensis* segments 1 and 4 are a little asymmetrical.

Leg 5 of female has two measurable characters that appear to vary but little in *alaskaensis* and are sufficiently different from *siberiensis*, as shown by Smirnov's drawing (1931, fig. 15) to permit relative comparison and separation of the two species. In *siberiensis* the inner margin of the second exopod segment (including the "claw") is apparently longer than the outer margin of the first segment; in *alaskaensis* it was usually found to be shorter. A more important difference lies in the third exopod segment, which, if correctly delineated by Smirnov, is as wide as it is long in *siberiensis*; its width in *alaskaensis* is about twice its length. Other differences which may or may not be real, lie in the greater slenderness of the appendage in *siberiensis*, the larger number of spinules on the "claw", the lack of much variability in the endopod, absence of asymmetry in the length and armature of a pair, and the stouter development of its single, apical seta.

Leg 5 of male. Right side: In *siberiensis* the first exopod segment has its outer margin only a little longer than its inner and greater than its width; in *alaskaensis* it is considerably longer than that of the inner and equal to its width; the armature of this segment appears to be very similar in form, but the lamellae of *siberiensis* are both placed above the distal margin of the segment, while those of *alaskaensis* are very close to it, so that of the inner edge is produced beyond the corner of the segment. The second exopod segment of *siberiensis* lacks a cuticular spine which is present in *alaskaensis*. *Left side:* In *siberiensis* the proximal process of the terminal segment reaches considerably beyond the end of the distal process; in *alaskaensis* this process reaches to the end of the distal process, or at most a very little beyond it; the distal process of *siberiensis* is armed on the inner margin with a few spinules; that of *alaskaensis* is unarmed. The distal pad of *siberiensis* appears to be a little more developed than that of *alaskaensis*, and is armed with slender instead of thick, short hairs.

DISTINCTIONS BETWEEN NORDODIAPTOMUS AND NEUTRODIAPTOMUS

Kiefer (1932) placed *D. siberiensis* in a list of species that he could not assign to any of his newly erected genera; in 1938 he referred it to *Neutrodiaptomus*. It is therefore necessary to compare the characters of this subgenus with *Nordodiaptomus*.

In establishing *Neutrodiaptomus* in 1937, Kiefer included the species *tumidus* Kiefer, *pachypoditus* Rylov, *amurensis* Rylov, and *mariadvigae* Brehm. To these he added (1938a) *incongruens* Poppe, *siberiensis* (as *D. rylovi* Smirnov), and *lobatus* Lilljeborg, the synonymy of the latter with *incongruens* appearing to him to be an uncertain matter. Hu (1943) described a new species *alatus*.

Of these species, *D. siberiensis* and *D. mariadvigae* appear to differ sharply from the consistently developed characters that hold the others together. *D. siberiensis* has been referred above to the new subgenus *Nordodiaptomus*. *D. mariadvigae* is apparently closely related to, if not conspecific with, the species *hsichowensis* recently described by Hsaio (1950). This species occurs in Yunnan, the same Chinese province in which Brehm's collection was made (Brehm, 1921, 1930). Hsaio considers that the lack of terminal setae on the endopod of the fifth leg of the female and the "pincerlike" structure of the processes of the left male fifth leg, though reduced in length, indicate relationship to *Arctodiaptomus*. He therefore made his new species the type of a subgenus *Pararctodiaptomus*. In the definition of *Diaptomus* used here, *Arctodiaptomus* is considered as a subgenus; the status of the various subgroups that have been proposed for it can be evaluated only when the whole of this subgenus is reinvestigated. It is possible that *Pararctodiaptomus* may be found to be of separate subgeneric status within the genus *Diaptomus*. This is particularly so if the distal pad of the male left fifth exopod is as well developed as is suggested by Hsaio's illustration; its loss or extreme reduction is highly characteristic of *Arctodiaptomus*.

So far as it is possible to ascertain from published descriptions, the remaining species of *Neutrodiaptomus* agree with one another very closely in several significant characters. From these, the species of *Nordodiaptomus* depart rather noticeably. Though agreeing in certain patterns, these two subgenera are naturally set apart by these differences. A brief comparison makes this clear.

The female fifth leg of *Neutrodiaptomus* has two short, equally developed setae on the terminus of the endopod; the pattern of the setae of exopod segments 2 and 3, identical in all the species, consists of a minute seta on 2, while on 3 there are a similar small outer and a much longer inner seta. *Nordodiaptomus* with the single spinelike seta of the endopod, and the stout, subequal setae of the exopod, is in sharp contrast. Indeed, these differences are among the most significant in separating the two groups, particularly the structure of the exopod setae which in *Nordodiaptomus* are of uncommon form for the whole genus.

The male right antennule has the pattern of segments 13–15 similar in both groups, but the spines of 10 and 11 are very short in *Neutrodiaptomus*, while they are of considerable stoutness in *Nordodiaptomus*; all species of *Neutrodiaptomus* have a hyaline lamella on the antepenultimate segment, in *Nordodiaptomus* this segment is unarmed. While these are characters that may vary within a group of related species, apparently their nonvariability may also distinguish a subgenus. This last seems especially true in *Neutrodiaptomus*; in our present knowledge there are no intermediate forms between it and *Nordodiaptomus*.

In the male right fifth leg of *Neutrodiaptomus*, the apical claw is never longer than the exopod, and the lateral spine, located at the proximal to the distal third, is usually less than the width of its segment. Both are of exceptional stoutness and length in *Nordodiaptomus*.

Any comparison between the patterns of the terminal segment of the left exopods is not wholly satisfactory because of the incompleteness of the descriptions of *Neutrodiaptomus*. The only enlarged drawings in literature are those of *tumidus* (Kiefer, 1938a) and *amurensis* (Rylov, 1930), and of these only *tumidus* is well enough described verbally to permit real comparison. The similarities of the two groups are: both pads are well defined and subequal to one another; the terminal process is short and digitiform; the proximal process is subterminal in position and about equal to or reaching a little beyond the distal. The differences between the two groups are more difficult to define; where it is possible to compare, the following are suggested.

The proximal pad in *Nordodiaptomus* is not merely a medially bulging structure, but is carried well across the anterior side of the segment and its shape is thus distinctly asymmetrical; it appears as a simple, medially placed pad in *Neutrodiaptomus*. The distal pad is conspicuously armed with slender to short, stout hairs in *Nordodiaptomus*; in *Neutrodiaptomus* there may be little or no armature of this pad. Kiefer (1938a) has described that of *tumidus* as a "lobus" and shows no ornamentation, as is also true of Rylov's (1930) figure of *amurensis*.

The proximal process of *Nordodiaptomus* is stout and spiniform; Smirnov describes that of *siberiensis* as a "spine" and my observations in *alaskaensis* confirm this. Kiefer speaks of those of *tumidus* and *pachypoditus* as "setae" and his illustrations picture this process as exceedingly slender. The difference between seta and spine is undoubtedly one of degree and is not always easy to determine. In this case it may merely be one of interpretation. The degree of stoutness and the form of this process, however, distinguishes other subgenera of *Diaptomus*, and it is necessary in the absence of any other evidence, to consider that these two groups are separable by the spiniform character of this process in *Nordodiaptomus* as opposed to its setiform development in *Neutrodiaptomus*.

It is unfortunate that for the species of *Neutrodiaptomus* no information is available concerning the highly important details of the maxilliped, the first leg, the cuticular process of the endopod of the second leg, the setation of the female antennule and its comparison to the male left antennule. Until taxonomists also include information about these points in their descriptions of diaptomid copepods, we will not be able to arrive at any satisfactory comparison of species or of subgenera. My study of North American species suggests that the development of the maxilliped, particularly of the setae of the endopod, the characters of the first leg, the presence or absence of Schmeil's organ on the endopod of the second leg, and the setation of the female antennule, are often as characteristic of subgenera as the modifications of the left exopod of the male fifth leg or the terminal setae of the endopod of the female fifth leg. They are in any case a part of the whole picture, and must be considered before any comprehensive evaluation of subgeneric or generic characters can be made.

In addition to its distinctions from *Neutrodiaptomus*, *Nordodiaptomus* departs in some characters from the usual condition found in *Diaptomus*. One such instance is that Schmeil's organ may be either present or absent, and interestingly is exhibited as a case of sexual dimorphism in one species. The numerical difference in setation of the antennules of the female and that of the left side of the male is the only one known to me in literature or in fact; investigation may show it to be more common than suspected. The contrast in the size of the setae of the first and second segments is not confined to *Nordodiaptomus*; Smirnov (1928) has noted the same sexual dimorphism in *D.* (*Arctodiaptomus*) *dentifer* which has a similarly elongate seta on segment 1 of the female. The structure of the exopod setae of the female fifth leg in *Neutrodiaptomus* is common throughout the genus; that of *Nordodiaptomus*, as suggested, is rather unusual. The asymmetry of the endopod of *Nordodiaptomus alaskaensis* is likewise a rare condition, impossible now to evaluate.

It thus appears that there occur in the two species of *Nordodiaptomus*, characters that differ naturally from consistently developed structures in *Neutrodiaptomus*, and in addition, that they have certain distinctive features which set them apart from other subgenera of *Diaptomus*. The inclusion of the two species in *Neutrodiaptomus* could be only provisional and would make the definition of that subgenus ambiguous in many parts. It seems best in my judgment to delimit the two groups as has been done herein.

It is probable that these two subgenera may be safely assumed to be closely related. This cannot now be proved, however, due to our lack of complete knowledge of some structures of *Neutrodiaptomus*, and our present inability to evaluate characters as subgeneric or otherwise.

The species of *Neutrodiaptomus* extend from subarctic into southeastern Asia. *Nordodiaptomus* is in our present knowledge limited to Arctic and subarctic regions of Asia and North America. The discovery of an Alaskan species closely related to one from the Asiatic U. S. S. R. adds to the growing list of examples that disprove the old concept that North American diaptomids are distinct from those of Eurasia. It is to be expected that further study of Alaskan collections will increase the number.

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HELMINTHOLOGY.—*A new roundworm,* Nematodirus rufaevastitatis (*Nematoda: Trichostrongylidae*) *from domestic sheep,* Ovis aries, *in Wyoming.* CHARLES G. DURBIN, U. S. Bureau of Animal Industry, and RALPH F. HONESS, University of Wyoming. (Communicated by E. W. Price.)

The nematodes described in this paper were collected by one of the writers (R. F. H.) from domestic sheep in the area of the Red Desert, Wyo., and western Wyoming during 1948 and 1949. The specimens were forwarded for identification to the Zoological Division, Bureau of Animal Industry. A study of them by the senior writer shows that they belong to the genus *Nematodirus.* They differ, however, from the known species of the genus in certain characters and they are, therefore, described as new.

Nematodirus rufaevastitatis, n. sp.

Description.—MALE: 11.5 to 15.3 mm long and about 0.1 mm wide just anterior to the bursa. Esophagus 0.430 to 0.500 mm long and about 0.030 to 0.040 mm wide at its base. Head 0.025 to 0.030 mm wide, as measured with the cuticle slightly inflated (Fig. 1, *A*). Spicules 1.0 to 1.15 mm long and united for about the posterior two-thirds of their total length; the tips have a slight membranous inflation (Fig. 1, *B*). The bursa consists of two large lateral lobes and a dorsal lobe which is indicated only by a slight indentation of the margin of the bursa lateral to the dorsal ray. The length of the bursa from its base to tip is 0.25 to 0.34 mm. Each lateral lobe of bursa is supported by six rays, two ventral, three lateral, and one externodorsal (Fig. 1, *C, D*). The two ventral rays arise from a common trunk and are long and slender. The three lateral rays likewise arise from a common trunk and are also long and slender. The mediolateral and postero-

lateral rays are close together. The externolateral branch curves ventrally away from the other two branches. The two dorsal rays arise separately. The externodorsal ray is long and very slender when compared with the other rays of the bursa. The dorsal ray is shorter and thicker than the externodorsal ray; the tip of the dorsal ray is not bifid as in the other described species of the genus.

Female: Unknown.

Host: Ovis aries.

Location: Small intestine.

Distribution: Wyoming, U.S.A.

Specimens: U.S.N.M. Helm. Coll. no. 46922 (type) and 46921 (paratypes).

This species closely resembles *N. spathiger* in the termination of the spicules (Fig. 1, *B*). It differs, so far as the writers are aware, from that species and from all others of the genus *Nematodirus* occurring in ruminants by the size of the bursa and the nonbifid tip of the dorsal ray. These species may be differentiated by the following key.

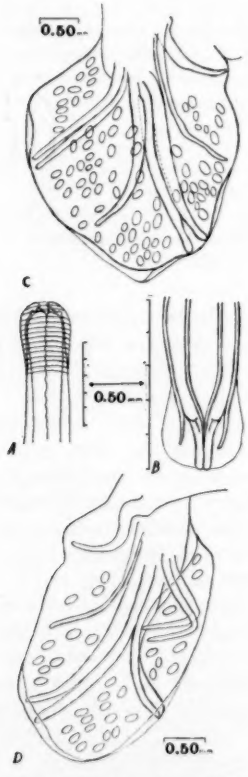

FIG. 1.—*Nematodirus rufaevastitatis*, n. sp.: *A*, Head; *B*, spicules; *C*, *D*, lateral lobes of bursa.

KEY TO MALES OF THE SPECIES OF NEMATODIRUS IN RUMINANTS

1. Terminal portions of dorsal rays undivided ..... *N. rufaevastitatis*, n. sp.
   Terminal portions of dorsal rays divided 2
2. Terminal portion of spicules bent ..... *N. tarandi* Hadwen
   Terminal portion of spicules straight 3
3. Small gubernaculum present ..... *N. urichi* Cameron
   Gubernaculum absent 4
4. Mediolateral and posterolateral rays well separated ..... *N. roscidus* Railliet
   Mediolateral and posterolateral rays close together 5
5. Spicules differing in length, terminal portion twisted ..... *N. abnormalis* May
   Spicules equal in length, terminal portion straight 6
6. Cuticular expansion of terminal portion of spicules spatulate ..... *N. spathiger* (Railliet)
   Cuticular expansion of terminal portion of spicules sharply pointed 7
7. Cuticular expansion of terminal portion of spicules 0.1 mm long ..... *N. helvetianus* May
   Cuticular expansion of terminal portion of spicules 0.06 to 0.08 mm in length 8
8. Terminal portion of each spicule divided into two rodlike structures united at the tips ..... *N. oiratianus* Rajewskaja
   Terminal portion of each spicule not divided ..... *N. filicollis* (Rudolphi)

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